Division of Agricultural Sciences
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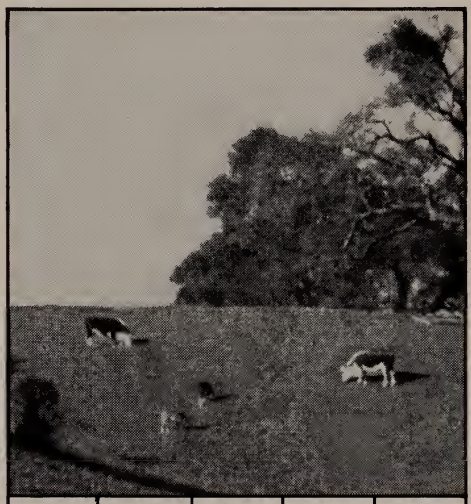
ECONOMIC STRATEGIES FOR FOOTHILL BEEF CATTLE RANCHERS



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The major problem for foothill range operation managers in California is to develop livestock systems which efficiently utilize a highly seasonal and extremely variable feed supply. Rising costs, particularly of rangeland, make it difficult to produce adequate income with traditional cattle programs. This study analyzes the economics of several beef cattle systems which were superimposed on the actual resources of a Sacramento Valley foothill ranch of about 4,000 acres. Linear programming and statistical decision theory are used in developing the optimum stocking rates and income levels for each beef cattle system.

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INTRODUCTION AND OBJECTIVES

There are about 30 million acres of foothill rangeland of various types in California, much of which is now used for beef cattle operations. The feed supply on this range reaches a peak in early spring and summer and diminishes sharply during the hot, dry summers and falls. Furthermore, climatic conditions vary widely from year to year and cause unpredictable fluctuations in feed conditions between years. Thus, a major problem of foothill range managers is how to utilize this variable feed supply most efficiently.

Many managers attempt to handle seasonal forage problems by integrating foothill range with irrigated pastures or with ranges at higher altitudes, because these provide forage in summer and early fall when feed on foothill ranges is scanty. However, many other foothill range operators, because of geographic location, lack of transportation facilities, or other factors, find such integration infeasible.

The case ranch studied in this report is of the latter type, in which the cattle operation must be tailored to the range supplies on the ranch and to purchased feeds. The ranch is located in the western foothills of the Sacramento Valley. Several alternative beef cattle programs are evaluated by superimposing them on the case-study ranch. Cow-calf and feeder operations were studied initially to establish income levels attainable from typical ranch organizations. Other, and more atypical, systems were then studied in order to evaluate income possibilities from more intensive operations. The six major plans examined were:

Plan 1: A beef cow herd, calves sold as weaners.

Plan 2: A beef cow herd, calves sold as yearlings.

Plan 3: An all-stocker operation, with 500-pound stockers bought in October.

Plan 4: An all-stocker operation, with 550-pound stockers bought in January.

Plan 5: A beef cow herd, calves sold as slaughter steers and heifers.

Plan 6: An all-stocker operation, with 500-pound stockers bought in October and sold as slaughter steers.

In Part I of this report each plan is examined for profitability under the assumption that "normal" or "average" weather and range conditions exist and that the optimum number of cattle are stocked for that range condition. Linear programming is used to derive the profit-maximizing stocking rates and the pasturing program for each of the plans. Linear programming is a useful mathematical tool for selecting the most profitable organization from among many possibilities, given certain basic resources and other restrictions (Heady and Candler, 1958).[2]

Part II of the report attempts to deal more realistically with the difficult question of optimum stocking rates and profits, given the risk and uncertainty of weather and varying prices. Statistical decision theory is used in developing various strategies to cope with risk and uncertainty. (A brief discussion of this theory will be found in Appendix B.)

[1] Submitted for publication March 10, 1965.

[2] See "Literature Cited" for publications referred to in text by author and date.

PREVIOUS ECONOMIC STUDIES OF FOOTHILL RANGE OPERATIONS

A 1957 study based on a 640-acre operation (Warren, 1957) estimated the following annual net farm incomes: $483 for a cow-calf operation with weaner calves sold at 400 pounds; $1,056 for a cow-calf operation with calves raised and sold as yearlings weighing 675–725 pounds; $2,833 for a seasonal feeder steer operation, with calves purchased in October–November and sold in June. The study reports that: "Neither labor (charges) nor interest on investment are included in (deriving the income) figures. To insert these two items into the calculations would result in large negative (income) figures." By the definitions used in the present study, management income was negative in these cases. A study of a 500-head feeder steer operation, utilizing 7,500 acres of range from October 1–June 1, resulted in a management income of $2,595 (Thurber and Parsons, 1958). A study based on 1,000 acres and an 80-cow herd, with calves sold as yearlings, estimated a net farm income of $4,560 and a management income of – $440 (Engvall, 1959). A study based on a 300-cow herd, with calves sold as yearlings, resulted in a management income of $3,914 (Helphenstine and Reed, 1962). Another study provided cost and returns data on conditions in the Central Coast area (Shultis and Strong, 1962). The study showed management returns per 125-head cow–calf operation of – $815, management returns for per 100-head cow operation with calves carried to yearling feeder weight of – $303, and management returns of $360 per 388 head of an all-stocker operation where calves are purchased and carried to yearling feeder weight. These studies suggest that the usual foothill range operation may return relatively little for management and, in many cases, not enough to provide market rates of interest on the invested capital. The present study will take the basic resources of the study ranch as given and then will investigate several methods of intensifying the operation to provide higher income levels. The resources of the study ranch are not completely typical (e.g., rangeland is probably above average in quality, and machinery investment is rather high), but the alternative plans and strategies evaluated should be informative for operators of more typical ranches.

DEFINITIONS OF INCOME MEASURES

Net cash income = cash receipts minus cash expenses.
Net farm income = cash receipts minus cash expenses minus depreciation.
Management income = cash receipts minus cash expenses minus depreciation minus nonpaid interest on capital investment.
(Note: Cash expenses include paid interest.)

DESCRIPTION OF RANCH RESOURCES

Land and Land Use Alternatives

Table 1 summarizes acreage, yields, and total production possibilities for various land uses on the study ranch. The higher grade range soils (so-called A soils), the soils used for range clovers, and the soils used for barley production are predominately of the Arbuckle, Corning, Hillgate, Kimball, Myers, and Perkins series. Approximately 700 acres of these lie in a contiguous valley strip and can be devoted to dryland barley (for grain, hay, or pasture); the remainder are hillside areas of moderate slope and flat ridgetop areas from which native scrub oak trees have been cleared. Of this area about 605 acres have been seeded to clovers (based on favored soil and exposure areas), 100 acres of which are in native burr clover. The major advantage of clover is that it can be cut and windrowed in the spring and used as dry feed later in the summer with little loss in feed value. The remainder of the A soils (500 acres) is used for native rangeland grasses. The lower grade soils of the ranch (so-called B soils) are predominately of the Lodo and Lodo Complex series. These soils are generally in the steeper areas and total 2,224 acres. In addition there are 25 acres of permanent irrigated pasture used primarily as a "hospital" area for sick cattle and as a temporary reserve pasture for limited numbers of cattle when dryland range supplies are short (not shown in table 1).

The fertilizer program on the range soils is as follows: The 500 acres of range A soils and half of the range B soils (1,112 acres) are fertilized every other year with 60 pounds of nitrogen (300 pounds of ammonium sulfate); the other half of the B soils do not respond significantly to fertilizer and remain untreated; the 605 acres of clover are fertilized every third year with 200 pounds of sulfur. Detailed cultural costs for establishment of the clover stand, and for barley and irrigated pasture, are shown in Appendix tables A-3, A-4, and A-5.

Table 1 also indicates the approximate yields per acre of the various land use

TABLE 1

ACREAGE, YIELDS, AND TOTAL PRODUCTION FOR VARIOUS LAND USES ON THE CASE-STUDY RANCH*

Types of soil and use	Acres	Unit	Spring (Feb. 15–May 31)		Fall (June 1–Oct. 31)	
			Yield per acre	Total production	Yield per acre	Total production
Range A soils†	500	AUM	1.50	750	1.12	560
Range B soils						
Fertilized†	1,112	AUM	0.75	834	0.56	623
Unfertilized†	1,112	AUM	0.40	445	0.30	334
Clover (range)†	605	AUM	1.50	908	1.50	908
Barley‡	700	....	....	....	....	....
Grain	....	Cwt.	18.00	....	....	....
Hay	....	Ton	2.00	....	....	....
Stubble (after grain and hay)	....	AUM	....	....	0.20	....
Pasture	....	AUM	3.33	....	3.33	....

* Yield estimates from manager of case-study ranch and from Monte Bell, Farm Advisor, Glenn County, Calif.

† Yields per acre refer to full grazing in either spring or fall. For example, Range A soils supply 1.50 AUM if fully grazed in spring or 1.12 AUM if not grazed in spring but fully grazed in the fall.

‡ Barley on 3-year rotation. A grain crop is taken in the first year. The volunteer crop in the next 2 years is used for hay or pasture.

possibilities under normal range conditions. For range and clover uses, the yield is divided into two separate periods: (1) the spring period corresponding approximately to a green forage period, and (2) the fall or dry forage period. The yields shown are for the first or the second period—hence, if an acre of A range is grazed intensely during the green forage period it provides 1.50 animal unit months (AUM) of forage during that period, and essentially no forage during the dry forage period. If the range A land is reserved for fall grazing only, the forage dries and is assumed to lose some 25 per cent in nutrient value, providing about 1.12 AUM per acre in the fall. All of the range forages except clover lose feed value if grazed in the fall rather than the spring.

The study ranch was fenced into several large fields with adequate watering ponds in each, thus permitting certain areas to be reserved for fall grazing. On many ranches it would be difficult to set aside specific areas for fall grazing without incurring substantial fencing costs.

Buildings, Machinery and Equipment, and Labor

Table 2 itemizes the buildings and the machinery and equipment owned by the study ranch. This inventory is probably somewhat excessive compared with the typical range operation, and the reader may wish to adjust the total fixed costs downward somewhat in interpreting incomes from the various plans. (The annual fixed costs of land, buildings, machinery and equipment, would vary only slightly among the plans considered in this report, hence these differences are ignored.) Fixed costs associated with the various items are taxes and insurance (cash fixed costs), depreciation (a deferrable fixed cost, but one which must be covered in the long run for the firm to stay in business) and interest on investment. Unless a loan is outstanding, the interest is only an imputed cost and need not necessarily be covered by earnings of the business. The totals of table 2 indicate that interest on the investment, because of the large investment in land, is by far the largest fixed cost item. Hence, the question of owner equity can be extremely critical, as shown by research studies cited earlier which indicate that earnings often are too small to permit a market rate of return on the entire investment. The assumption in this study is that the operator has 100 per cent equity in land, buildings, machinery and equipment, but borrows to finance the livestock operation.

The labor force on the range consists of a manager and one full-time man, plus one or two men hired seasonally for about 6 months per year each. The exact combination of laborers depends upon the labor requirements and seasonal labor peaks of the various plans. The full-time help is paid at the rate of $4,500 per year and the seasonal help at $4,000 per year. The labor requirement in this study is slightly higher than often appears in studies of range beef cattle operations (Shultis and Strong, 1962). However, the study farm has a greater than average acreage of barley grain and hay land, range fertilization is practiced, there is a high rate of culling, and generally there is a rather close supervision, all of which requires more labor.

Cattle Prices

Production, cost, and returns data are detailed for each individual plan. However, a critical element common to all of the programs is the price of purchase and

TABLE 2

CAPITAL INVESTMENT AND ANNUAL FIXED COSTS ON CASE-STUDY RANCH

Description	Initial cost	Estimated useful life	Average investment	Annual depreciation*	Taxes and insurance†	Interest on investment§
	dollars	*years*	*dollars*			
Land	225,000.00	..	225,000.00	.....	2,925.00‡	13,500.00
Buildings and improvements						
Barn	490.00	20	245.00	24.50	4.90	17.15
Barn	5,000.00	20	2,500.00	250.00	50.00	175.00
Feed room	500.00	20	250.00	25.00	5.00	17.50
Mangers	358.00	20	179.00	17.90	3.58	12.53
Implement shed	5,000.00	20	2,500.00	250.00	50.00	175.00
Range fence	17,897.00	20	8,948.50	894.85	178.97	626.40
Culverts	678.00	10	339.00	67.80	6.78	23.73
Irrigation pipe trailer	257.00	10	128.50	25.70	2.57	9.00
Irrigation system	9,053.00	10	4,526.50	905.30	90.53	316.86
Sprinkler pipe	2,000.00	10	1,000.00	200.00	20.00	70.00
Pump and motor	2,000.00	10	1,000.00	200.00	20.00	70.00
Sprinkler system	866.00	10	433.00	86.60	8.66	30.31
Subtotal	44,099.00	..	22,049.50	2,947.65	440.99	1,543.48
Ranch vehicles						
Dump truck	1,227.00	10	613.50	122.70	12.27	42.94
Pickup	978.00	5	489.00	195.60	9.78	34.23
Jeep	2,069.00	5	1,034.50	413.80	20.69	72.42
Jeep	1,691.60	5	845.80	338.32	16.92	59.21
Subtotal	5,965.60	..	2,982.80	1,070.42	59.66	208.80
Cultural machinery and equipment						
D4	8,600.00	15	4,300.00	573.33	86.00	301.00
Farmall 450	6,000.00	10	3,000.00	600.00	60.00	210.00
Ford tractor	2,000.00	10	1,000.00	200.00	20.00	70.00
Rear-mounted mower	186.00	10	93.00	18.60	1.86	6.51
Dump rake	75.00	10	37.50	7.50	0.75	2.62
Baler	1,119.00	10	559.00	111.90	11.19	39.16
Bale loader	224.00	10	112.00	22.40	2.24	7.84
Stubble plow	2,100.00	10	1,050.00	210.00	21.00	73.50
Two 10-inch discs	1,900.00	10	950.00	190.00	19.00	66.50
Two-way plow	4,000.00	10	2,000.00	400.00	40.00	140.00
Chain harrow	150.00	10	75.00	7.50	1.50	5.25
Grass seeder	895.00	10	447.50	89.50	8.95	31.32
Grain drill	597.00	10	298.50	59.70	5.97	20.90
Broadcast seeder	75.00	10	37.50	7.50	0.75	2.62
Seed mixer	232.00	10	116.00	23.20	2.32	8.12
Posthole auger	112.00	10	56.00	11.20	1.12	3.92
Terracer blade	75.00	10	37.50	7.50	0.75	2.62
Front end loader	261.00	10	130.50	26.10	2.61	9.14
Two wagons (four wheel)	149.00	10	74.50	14.90	1.49	5.22
Engine	196.00	10	98.00	19.60	1.96	6.86
Subtotal	28,946.00	..	14,473.00	2,600.43	289.46	1,013.10
Livestock equipment						
Stock water system	3,853.00	10	1,926.50	385.30	38.53	134.86
Stock water pump	186.00	10	93.00	18.60	1.86	6.51
Castrating table	130.00	10	65.00	13.00	1.30	4.55
Squeeze	260.00	10	130.00	26.00	2.60	9.10
Feed bins	1,731.00	20	865.50	86.55	17.31	60.58
Elevator and motor	175.00	10	87.50	17.50	1.75	6.12
Elevator	173.00	10	86.50	17.30	1.73	6.06
Molasses tank	1,228.00	10	614.00	122.80	12.28	42.98
Subtotal	7,736.00	..	3,868.00	687.05	77.36	270.76
Total (excluding land)	86,746.60	..	43,373.30	7,305.55	867.47	3,036.14
Total (including land)	311,746.60	..	.....	7,305.55	3,792.47	16,536.14

* Straight line method, assuming no salvage value.
† Figured at 1 per cent of initial cost.
‡ $0.65 per acre for 4,500 acres.
§ Seven per cent of average investment except land at 6 per cent of initial cost.

TABLE 3

ASSUMED PRICES FOR CATTLE*

Month	Slaughter steers		Slaughter heifers		Stocker and feeder steers		Stocker and feeder heifers		Steer calves	Heifer calves	Slaughter cows, utility (all weights)
	Choice (900–1,100 pounds)	Good (900–1,100 pounds)†	Choice (900–1,100 pounds)	Good (800–1,000 pounds)‡	Choice (500–800 pounds)	Good (500–800 pounds)	Choice (500–750 pounds)	Medium and good (500–750 pounds)	Good and choice (300–500 pounds)	Good and choice (300–500 pounds)	
	dollars per hundredweight										
January	24.37	22.89	22.97	21.58	23.78	22.31	20.90	18.99	25.22	22.59	15.66
February	24.16	22.75	22.72	21.43	24.24	22.66	21.32	19.20	25.74	23.13	15.63
March	25.09	23.44	24.89	22.22	24.82	23.34	22.13	20.96	26.58	23.85	16.56
April	25.58	23.93	24.26	22.83	24.90	23.36	22.39	20.11	26.40	24.07	16.51
May	25.59	23.98	24.41	22.77	24.62	23.12	22.13	19.81	25.85	23.57	16.42
June	25.58	23.69	23.85	22.52	24.10	22.59	21.81	18.76	25.12	22.98	16.05
July	25.52	23.63	24.14	22.39	23.93	22.58	21.57	19.19	24.95	22.60	15.90
August	25.24	23.27	23.79	22.03	23.79	22.50	21.35	18.98	24.50	22.25	15.36
September	24.68	23.06	23.16	21.95	23.76	22.52	21.32	18.23	25.03	22.50	15.63
October	24.06	22.69	22.65	21.60	23.57	22.29	21.11	18.80	25.18	22.40	15.41
November	23.77	22.51	22.65	21.28	23.71	22.46	21.16	18.71	25.34	22.49	15.37
December	24.99	23.37	23.46	21.90	24.18	22.89	21.58	19.20	26.00	23.00	15.81

* 1956–62 average Stockton, California prices. SOURCE: USDA Federal-State Market News Service, 1961, 1962.
† 800–1,000 pounds prior to January, 1960.
‡ 700–900 pounds prior to January, 1960.

sale of beef cattle. Table 3, which is based on a 7-year average of prices at Stockton, reveals a seasonality in beef prices which may be important in the relative profitability of different buying and selling programs for feeder cattle. Hence, these prices, rather than a fixed year-around price, are used in the analysis.

I. OPTIMUM PLANS FOR AVERAGE PRICES AND RANGE CONDITIONS

Beef Cow Operations

Plan 1. Beef Cow Herd, Calves Sold as Weaners

Plan 1 is a cow–calf operation organized typically for a foothill ranch. Cows and heifers are bred from February 1–May 1 and calve November 1–February 1. Ninety per cent of the cows produce live calves; at weaning time, the calf crop is 88 per cent. Breeding is by bulls rather than artificial insemination. The steer calves are sold when about 8 months old, weighing 480 pounds; heifer calves are retained until about 1 year old, at which time the replacement heifers are selected (replacement rate is 20 per cent per year) and the remaining heifers sold at about 605 pounds. Hence, the replacement heifers are bred when about 15 months old, and they calve when about 2 years old. This relatively rigorous program of cow culling and heifer selection accounts for the favorable calving percentage and rates of gain on the calves.

Table 4 provides a detailed summary of data used in the cow–calf operation. For convenience, data are based on a 100-cow herd at calving time, although several herd sizes are considered at later points in the report.

Given these basic data on the cow–calf operation and the basic pasture resources described earlier (table 1), linear programming is used to derive the maximum size of cow herd consistent with pasture supplies. The text table below indicates the results, showing a 360-cow herd and the optimum allocation of the various types of pasture between spring and fall grazing. In this plan the lower quality range (B soil) is used for spring green forage grazing, while most of the higher-producing range (A soil) and the clover range is set aside for use in the long fall dry forage period. In addition, 389 acres of barley stubble (233 of grain stubble and 156 of hay stubble) and 311 acres of barley pasture are required to

CATTLE NUMBERS AND ALLOCATIONS OF FEED SUPPLIES FOR PLAN 1; BEEF COW HERD, CALVES SOLD AS WEANERS

CATTLE PROGRAM	HEAD
Beef cow herd	360
PASTURE PROGRAM	**ACRES**
Range A (spring feed)	174
Range A (fall feed)	326
Range B (spring feed)	2,224
Clover (fall feed)	605
Barley	
Grain	233
Hay	156
Stubble (fall feed after grain and hay)	389
Pasture	311
Irrigated pasture (spring and fall)	25

TABLE

ASSUMPTIONS UNDERLYING PLAN 1: BEEF

Month	Approximate number of cattle, by type (100-cow herd)†				Pasture requirements per head‡			
	Cows	Bulls	Calves and weaners	Replacement heifers	Cows	Bulls	Calves and weaners	Replacement heifers
	number				*AUM*			
November	81	4	44	19	...	...	....	....
December	100	4	90	20	...	...	....	....
January	90	4	89	20	...	...	....	....
February (1–15)	90	4	88	20	...	...	....	....
Winter total	..	..	..	..	...	...	....	....
February (15–28)	90	4	88	20	1.0	1.0	0.15	0.30
March	88	4	88	20	1.0	1.0	0.20	0.65
April	88	4	88	20	1.0	1.0	0.25	0.65
May	88	4	88	20	1.0	1.0	0.30	0.70
Spring total	..	..	..	..	...	...	....	....
June	88	4	88	20	1.0	1.0	0.40	0.75
July	88	4	88	20	1.0	1.0	0.45	0.80
August	82	4	44	20	1.0	1.0	0.55	0.85
September	82	4	44	19	1.0	1.0	0.60	0.90
October	81	4	44	19	1.0	1.0	0.60	0.95
Fall total	..	..	..	..	...	...	....	....
Annual total	..	..	..	..	...	...	....	....

* Based on following general assumptions:
1. Breeding: Cows and heifers bred February 1–May 1; four bulls per 100 cows; 88 per cent calf crop; calves born November 1–February 1.
2. Replacement: 20 per cent replacement rate; first-calf heifers bred at 15 months.
3. Calves: Weigh 70 lb. at birth (November 1–February 1). Steers gain 1.8 lb. per day, weaned and sold at 8 months (July 1–October 1) weighing 500 lb. (480 lb. after 4 per cent shrink). Heifers gain 1.6 lb. per day, weaned at 8 months weighing 450 lb. All heifers are retained until 1 year old; 20 per cent used for replacements, 80 per cent sold at 630 lb. (605 lb. after 4 per cent shrink).
4. Death loss: Cows and bulls, 2 per cent per year; calves from birth to weaning, 3 per cent.

carry the animals through fall grazing. In fall and winter the animals are supplemented according to the feeding schedule shown in table 4.

Cost-sheet 1 gives estimated gross income, costs and various measures of net income associated with plan 1. Net cash income (cash receipts minus cash expenses including interest paid on livestock investment) is $7,229. Subtracting depreciation of $7,306 leaves a net farm income of −$77, which represents the earnings remaining to service farm debt and to pay the operator for his management and labor. However, the investment in this operation amounts to approximately $355,000 ($225,000 for land, approximately $45,000 for improvements, machinery and equipment, and about $85,000 for livestock). Thus, interest on the investment (7 per cent of the average machinery investment and 6 per cent of the other capital items) is $16,536, and, when subtracted from net farm income, leaves a management income of −$16,613.

Although fixed costs in the depreciation and interest on investment categories may be somewhat high on the study ranch because of the relatively high-priced land

COW HERD, CALVES SOLD AS WEANERS*

Total pasture requirements, all stock (100-cow herd)	Supplementary feeding§								Total supplementary feed, all stock (100-cow herd)		
	Cows and mature replacement heifers		Weaners and young replacement heifers			Bulls					
	Cotton-seed meal	Barley hay	Cotton-seed meal	Barley hay	Barley grain	Cotton-seed meal	Barley hay	Barley grain	Cotton-seed meal	Barley hay	Barley grain
AUM	*pounds per head per day*								*tons*		
...	2.0	14	1.5	8	1.5	2.0	14	5	4.11	27.12	1.29
...	2.0	14	1.5	8	1.5	2.0	14	5	3.57	24.24	0.75
...	2.0	14	1.5	8	1.5	2.0	14	5	3.27	22.14	0.75
...	2.0	14	1.5	8	1.5	2.0	14	5	1.63	11.07	0.38
...	...	..	...	..	...	...	..	..	12.58	84.57	3.17
53	...	..	...	..	...	...	..	..	.....	.....	.....
123	...	..	...	..	...	...	..	..	.....	.....	.....
127	...	..	...	..	...	...	..	..	.....	.....	.....
132	...	..	...	..	...	...	..	..	.....	.....	.....
435	...	..	...	..	...	...	..	..	.....	.....	.....
142	...	..	...	..	...	...	..	..	.....	.....	.....
148	...	..	...	..	..	2.0	10	..	0.12	0.60	.....
127	1.0	..	1.5	..	...	2.0	10	..	2.64	0.60	.....
130	1.5	..	1.5	..	...	2.0	10	5	3.39	0.60	0.30
129	1.5	..	1.5	..	...	2.0	10	5	3.36	0.60	0.30
676	...	..	...	..	...	...	..	..	9.51	2.40	0.60
1,111	...	..	...	..	...	...	..	..	22.09	86.97	3.77

† For simplicity, cattle numbers are shown as if all cows calve on December 1 (90 calves); with death losses 88 calves are weaned and the 44 steer calves sold August 1. The 44 heifer calves are carried to December 1, at which time 24 are sold and 20 become replacement heifers. These 20 replacement heifers are bred about March 1 and (with one death loss) the 19 heifers are added to the 81 cows (in the following December) to total 100 cows which are due to calve.

‡ SOURCE: Shultis, *Beef Cattle on Irrigated Pasture*, University of California Agr. Ext. Service (Mimeo. unnumbered), October, 1954.

§ Based, with some modification on: W. H. Johnson and H. T. Strong, *Supplemental Feeding of Beef Cattle on the Range*, California Agr. Expt. Sta. Leaflet 11 (Rev.), June, 1958.

and the somewhat heavy machinery inventory, large reductions could take place in these cost items without materially changing the general profit picture. For example, if both of these items were overestimated by 50 per cent, the net farm income and mangement income would increase only to $5,424 and −$8,666, respectively. The basic difficulty with this plan is the small volume of business (net cash income of only $7,229). A second qualification of the results regards the handling of interest on investment. It has been assumed that the owner finances his cattle with a lending agency and therefore pays interest as a cash cost. If he financed cattle from his own funds, this interest would be a non-cash charge in the form of an opportunity cost, and his net farm income would be raised by $5,104.

This plan provides only about enough volume of business to cover cash costs and to replace capital equipment, and nothing would remain as a payment to capital and management; therefore, it would be extremely difficult to stay in business in the long run without outside funds. If depreciation has been overestimated by 50 per cent, the plan would cover cash

COST SHEET 1. COSTS, RETURNS, AND INCOME FOR PLAN 1; 360-HEAD BEEF COW HERD, CALVES SOLD AS WEANERS

GROSS INCOME	
Cash receipts	
4 bulls, 1,500 lb., sold at $20.00 per cwt.	$ 1,200
33 utility cows, 1,000 lb., sold Jan. 1 at $15.74 per cwt.	5,194
7 utility cows, 1,000 lb., sold Mar. 1 at $16.10 per cwt.	1,127
22 utility cows, 1,000 lb., sold Aug. 1 at $15.63 per cwt.	3,439
158 good-choice steer calves, 480 lb., sold July–Sept. at $24.83 per cwt.	18,831
86 good–choice yearling heifers, 605 lb., sold Nov.–Jan. at $20.09 per cwt.	10,453
3,923 cwt. barley at $1.90 per cwt.	7,454
Subtotal	$47,698
COSTS	
Cash variable costs	
Cultural	
Fertilize 202 acres of clover each year at $4.40 per acre	$ 889
Fertilize 500 acres of Range A every other year at $6.00 per acre	1,500
Fertilize 1,112 acres of Range B every other year at $6.00 per acre	3,336
Produce 233 acres of barley grain at $20.65 per acre	4,811
Produce 156 acres of barley hay at $10.94 per acre	1,707
Prorated cost of establishing 500 acres of clover at $2.50 per acre per year	1,250
Annual costs for 25 acres of irrigated pasture	728
Subtotal	$14,221
Livestock	
Veterinary and medicine, 360-cow herd at $1.50 per head per year	$ 540
Buy 4 replacement bulls at $500 per head	2,000
Buy 80 tons of cottonseed meal at $75.00 per ton	6,000
Buy salt ($30.00 per 100 cows)	108
Transportation out for 62 cull cows, 244 calves, and in and out for 4 bulls = 201,870 lb. at $0.36 per cwt.	727
Buy alfalfa hay 26.4 tons at $25.00 per ton	660
Subtotal	$10,035
Cash fixed costs	
Labor—1 full-time and one seasonal worker ($4,500 per year per full-time man)	$ 6,500
Taxes and insurance (machinery and equipment)	867
Property tax—land and buildings $0.65 per acre × 4,500 acres	2,925
Taxes—cattle, $1.80 per cow, bull, or heifer replacement; $0.35 per calf	817
Interest—389 cows and heifers at $150.00; 263 calves at $75.00; 14 bulls at $500.00. $85,075 at 6 per cent.	5,104
Subtotal	$16,213
Depreciation	
Machinery and equipment, fences, buildings	7,306
Interest on investment (opportunity cost)	
Machinery and equipment, fences, buildings	3,036
Land—4,500 acres at $50.00 per acre = $225,000.00 at 6 per cent	13,500
Subtotal	$16,536
NET INCOME	
Net cash income	$ 7,229
Net farm income	— 77
Management income	—$16,613

costs plus depreciation but would not return a market rate of interest on capital investment. Operators who own their ranches and equipment free of debt and who can finance their own cattle would be able to continue in business with the plan, although they would be accepting rates of return on their capital and management far below market rates. This agrees with the experience of many foot-

TABLE 5

ASSUMPTIONS UNDERLYING PLAN 2; BEEF COW HERD, CALVES SOLD AS YEARLINGS*

Month	Approximate number of cattle, by type, (100-cow herd)†					Pasture requirements per head, by type‡					Total pasture requirements, all stock (100-cow herd)	Supplementary feeding (per head per day)§	Total supplementary feed, (100-cow herd)		
	Cows	Bulls	Calves and weaners	Yearlings	Replacement heifers	Cows	Bulls	Calves and weaners	Yearlings	Replacement heifers			Cottonseed meal	Barley hay	Barley grain
	number					*AUM*					*AUM*	*pounds*	*tons*		
November	81	4	87	..	19	...	...	....	....	....	....	Same as in table 4	5.07	32.28	2.25
December	81	4	87	..	19	...	...	....	....	....	....		5.07	32.28	2.25
January	100	4	90	67	20	...	...	....	....	....	....	(Yearlings receive	5.07	32.28	2.25
February (1–15)	90	4	89	67	20	...	...	....	....	....	....	same as replacement heifers)	2.35	15.09	1.12
Winter total	..	..	..	..	..	...	...	....	....	....	....		17.56	111.93	7.87
February (15–28)	90	4	89	67	20	1.0	1.0	0.10	0.65	0.65	80		.....	.....	.....
March	90	4	88	67	20	1.0	1.0	0.15	0.65	0.65	164		.....	.....	.....
April	88	4	88	67	20	1.0	1.0	0.20	0.70	0.70	170		.....	.....	.....
May	88	4	88	..	20	1.0	1.0	0.25	....	0.75	129		.....	.....	.....
Spring total	..	..	..	..	..	...	...	....	....	....	543		.....	.....	.....
June	88	4	88	..	20	1.0	1.0	0.30	....	0.75	133		.....	.....	.....
July	88	4	88	..	20	1.0	1.0	0.40	....	0.80	143		0.12	0.60	.....
August	88	4	88	..	20	1.0	1.0	0.45	....	0.85	149		3.72	0.60	.....
September	82	4	88	..	20	1.0	1.0	0.55	....	0.90	152		4.40	0.60	0.30
October	82	4	87	..	19	1.0	1.0	0.60	....	0.95	156		4.35	0.60	0.30
Fall total	..	..	..	..	..	...	...	....	....	....	733		12.59	2.40	0.60
Annual total	..	..	..	..	..	...	...	....	....	....	1,276		30.15	114.33	8.47

* Based on the following general assumptions:

1. Breeding: Cows and heifers bred March 1–June 1; four bulls per 100 cows; 88 per cent calf crop; calves born December 1–March 1.
2. Replacement: 20 per cent replacement rate; first-calf heifers bred at 15 months.
3. Calves: Weigh 70 lb. at birth (assume January 1). Steers gain 1.8 lb. per day, weaned at eight months (September 1); September 1 to March 1 gain 1.0 lb. per day on supplementary winter feeding; March 1–May 1 gain 1.2 lb. per day; sold May 1 weighing 750 lb. (720 lb. after 4 per cent shrink). Heifers gain 1.6 lb. per day until weaned at 8 months (September 1); September 1 to March 1 gain 0.9 lb. per day; March 1–May 1 gain 1.1 lb. per day; sold May 1 weighing 680 lb. (650 lb. after 4 per cent shrink).
4. Death loss: Cows and bulls, 2 per cent per year; calves from birth to weaning, 3 per cent.

† Cattle numbers are shown as if all cows calve on January 1 (90 calves); with death losses, 88 calves are weaned (September 1). All calves are wintered on supplementary feeding. On January 1, 20 heifers are selected as replacements, the remaining 64 head are put on pasture in spring and sold as feeders May 1. The 20 replacement heifers are bred about March 1 and (with one death loss) the 19 heifers are added to the 81 cows on the following January 1 to total 100 cows due to calve.

‡ SOURCE: Shultis, *Beef Cattle on Irrigated Pasture*, University of California Agr. Ext. Service (mimeo. unnumbered), October 1954.

§ See table 4.

hill range operators attempting to use a beef cow herd on high-priced range. Some operators who inherited their ranches debt-free, or who purchased rangeland years ago at lower prices, manage to continue in business with a beef cow herd. But an operator today could not ordinarily buy a foothill ranch at present prices and pay for it out of earnings from a cow–calf operation. It should be reemphasized that this and the succeeding plans assume relatively high-quality land resources and good management practices throughout the crop and livestock organization.

Plan 2. Beef Cow Herd, Calves Sold as Yearlings

Plan 2 is another typical foothill range organization with a beef cow herd where calves are sold as yearlings. Plan 2 is thus essentially the same as plan 1, except that the calves are not sold as weaners in the fall but are retained through the winter and spring. They are sold about May 1 (16 months of age), with the steers weighing 720 pounds and the heifers 650 pounds. Because the yearlings require pasture in the spring, the number of cows must be reduced from 360 head (plan 1) to 312 head (plan 2) and the pasture utilization plan revised. Table 5 shows the basic assumptions underlying the program. The text table following, and cost-sheet 2, show the cattle numbers, feed utilization pattern, and costs and returns for plan 2.

CATTLE NUMBERS AND ALLOCATION OF FEED SUPPLIES FOR PLAN 2; BEEF COW HERD, CALVES SOLD AS YEARLINGS

CATTLE PROGRAM	HEAD
Beef cow herd	312
PASTURE PROGRAM	**ACRES**
Range A (spring feed)	254
Range A (fall feed)	246
Range B (spring feed)	2,224
Clover (fall feed)	605
Barley	
Grain	233
Hay	176
Stubble (fall feed after grain and hay)	409
Pasture	291
Irrigated pasture (spring and fall)	25

Because cow numbers must be reduced to release range forage supplies necessary for carrying calves to yearlings, the gross income from plan 2 (cost-sheet 2) increases by only about $200 over that from the cow–calf operation. The conclusions also are similar: at present prices a beef cow herd, with calves sold as yearlings, does not generate sufficient income to provide a market rate of return on capital investment or management. Because of the uncertainty of range feed supplies, some ranches carry a smaller breeding herd than is needed to use all the feed in an average year. A variable number of stockers are then purchased in an attempt to utilize the feed supply in the particular year. Such flexible plans are considered in more detail in Part II of this report.

All-stocker Operations

A beef cow herd produces only a limited output from a range operation. The cows have a relatively high year-around feed requirement and output is limited to the calves, which are carried to varying stages in the growing process. One way to increase volume of output and gross income is to eliminate the cows entirely and replace them with purchased stockers, all of which are ultimately sold.

COST-SHEET 2. COSTS, RETURNS, AND INCOME FOR PLAN 2: 312-HEAD BEEF COW HERD, CALVES SOLD AS YEARLINGS

GROSS INCOME	
Cash receipts	
4 bulls, 1,500 lb., sold at $20.00 per cwt.	$ 1,200
28 utility cows, 1,000 lb., sold Feb. 1 at $15.64 per cwt.	4,379
6 utility cows, 1,000 lb., sold Apr. 1 at $16.54 per cwt.	992
19 utility cows, 1,000 lb., sold Sept. 1 at $15.50 per cwt.	2,945
137 good-choice feeder steers, 720 lb., sold May 1 at $23.49 per cwt.	23,171
72 good-choice feeder heifers, 650 lb., sold May 1 at $20.55 per cwt.	9,617
3,665 cwt. barley at $1.90 per cwt.	6,964
Subtotal	$49,268
COSTS	
Cash variable costs	
Cultural	
Fertilize 202 acres of clover each year at $4.40 per acre	$ 889
Fertilize 500 acres of Range A every other year at $6.00 per acre	1,500
Fertilize 1,112 acres of Range B every other year at $6.00 per acre	3,336
Produce 233 acres of barley grain at $20.65 per acre	4,811
Produce 176 acres of barley hay at $10.94 per acre	1,925
Prorated cost of establishing 500 acres of clover at $2.50 per acre per year	1,250
Annual cost for 25 acres of irrigated pasture	728
Subtotal	$14,439
Livestock	
Veterinary and medicine, 312-cow herd at $1.50 per head per year; 209 yearlings at $1.00 per head per year	$ 677
Buy 4 replacement bulls at $500.00 per head	2,000
Buy 94 tons of cottonseed meal at $75.00 per ton	7,050
Buy salt ($30.00 per 100 cows)	94
Transportation out for 53 cull cows, 209 feeders, and in and out for 4 bulls = 210,440 lbs. at $0.36 per cwt.	758
Buy 6 tons alfalfa hay at $25.00 per ton	150
Subtotal	$10,729
Cash fixed costs	
Labor—1 full-time and one seasonal worker ($4,500.00 per year per full-time man)	$ 6,500
Taxes and insurance (machinery and equipment)	867
Property tax—land and buildings	2,925
Taxes—cattle, $1.80 per cow, bull, or heifer replacement; $0.35 per calf or yearling	668
Interest—337 cows and heifers at $150.00 (year); 275 calves at $100.00 (year); 209 yearlings at $130.00 (5 months); 12 bulls at $500.00 (year). Interest at 6 per cent.	5,722
Subtotal	$16,682
Depreciation	
Machinery and equipment, fences, buildings	$ 7,306
Interest on investment	
Machinery and equipment, fences, buildings	3,036
Land—4,500 acres at $50.00 per acre = $225,000.00 at 6 per cent	13,500
Subtotal	$16,53
NET INCOME	
Net cash income	$ 7,418
Net farm income	$ 112
Management income	−$16,424

Whether this step results in greater net income depends on a number of factors, most important of which are prices and daily gains.

This section summarizes the results of two types of stocker operations. In the first (plan 3), 500-pound steers are purchased October 1, and sold June 1. In

TABLE 6

PASTURE, FEED REQUIREMENTS, AND DAILY GAINS FOR LIVESTOCK ASSOCIATED WITH STOCKER CATTLE PROGRAMS, PLANS 3 AND 4

Time	Light steers, bought Oct. 1—sold June 1 (plan 3)*					Heavy steers, bought Jan. 1—sold July 1 (plan 4)‡				
	Pasture	Cotton-seed meal	Barley hay	Barley grain	Daily gains	Pasture	Cotton-seed meal	Barley hay	Barley grain	Daily gains
	AUM	*pounds per day*				*AUM*	*pounds per day*			
Nov. 1–Feb. 15	....	1.5	8	1.5	1.0	....	1.5†	8†	1.5†	1.0†
Feb. 15–March 1	0.35	...	..	...	1.0	0.30	...	..	...	1.0
March	0.70	...	..	...	1.2	0.65	...	..	...	1.2
April	0.75	...	..	...	1.2	0.70	...	..	...	1.2
May	0.75	...	..	...	1.2	0.70	...	..	...	1.2
Spring total	2.55	...	..	...	...	2.35	...	..	...	...
June	....	...	..	...	...	0.75	...	..	...	1.2
July	....	...	..	...	...	....	...	..	...	...
August	....	...	..	...	...	....	...	..	...	...
September	....	...	..	...	...	....	...	..	...	...
October	0.55	1.5	..	...	1.0	....	...	..	...	...
Fall total	0.55	...	..	...	...	0.75	...	..	...	...

* Based on the following general assumptions: 500-lb. steers bought about Oct. 1. Gain as shown in table, sold weighing 760 lb. (730 lb. after 4 per cent shrink) about June 1. Grade 50 per cent good, 50 per cent choice at sale, 1 per cent death loss.

† From Jan. 1 to Feb. 15 only.

‡ Based on the following general assumptions: 550-lb. steers bought about Jan. 1. Gain as shown in table, sold weighing 755 lb. (725 lb. after 4 per cent shrink) about July 1. Grade 50 per cent good, 50 per cent choice at sale, 1 per cent death loss.

the second (plan 4), heavier 550-pound steers are purchased later (about January 1) and sold July 1. Table 6 shows the basic assumptions underlying these two plans.

Plan 3. All-stocker Operation, with 500-pound Steers Bought in October

The text table below shows that with an optimum allocation of normal range supplies, the study ranch can handle 1,210 head of light steers purchased October 1 and sold June 1. The heavy grazing requirement in the spring means that most of the pasture is allocated to that period. Only enough clover (379 acres) and barley stubble (487 acres) are set aside to carry the steers through October after they are purchased. The animals are supplemented through winter until range is again available (about February 15).

CATTLE NUMBERS AND ALLOCATION OF FEED SUPPLIES FOR PLAN 3: ALL-STOCKER OPERATION, WITH 500-POUND STEERS BOUGHT OCTOBER 1

CATTLE PROGRAM	HEAD
Good–choice calves, sold as feeders	1,210
PASTURE PROGRAM	**ACRES**
Range A (spring feed)	500
Range B (spring feed)	2,224
Clover (spring feed)	226
(fall feed)	379
Barley Grain	233

Hay	254
Stubble (fall feed after grain and hay)	487
Pasture (spring feed)	213
Irrigated pasture (spring and fall)	25

Cost-sheet 3 summarizes costs, returns, and income for plan 3. The gross volume of business is of course much larger than for the beef cow herd operations (about $213,000 *vs.* about $48,000–$50,000). However, cash costs including purchasing the calves also are much higher, leaving a net cash income of $16,707, some $9,000–$9,500 higher than for the beef cow operations. Net farm income and management income also are

COST-SHEET 3. COSTS, RETURNS, AND INCOME FOR PLAN 3; 1,210-HEAD ALL-STOCKER OPERATION, WITH 500-POUND STEERS BOUGHT OCTOBER 1

GROSS INCOME	
Cash receipts	
1,210 good-choice feeder steers, 730 lb., sold June 1 at $23.61 per cwt.	$208,547
2,283 cwt. barley at $1.90 per cwt.	4,338
Subtotal	$212,885
COSTS	
Cash variable costs	
Cultural	
Fertilize 202 acres of clover each year at $4.40 per acre	$ 889
Fertilize 500 acres of Range A every other year at $6.00 per acre	1,500
Fertilize 1,112 acres of Range B every other year at $6.00 per acre	3,336
Produce 233 acres of barley grain at $20.65 per acre	4,811
Produce 254 acres of barley hay at $10.94 per acre	2,779
Prorated cost of establishing 500 acres of clover at $2.50 per acre per year	1,250
Annual costs for 25 acres of irrigated pasture	728
Subtotal	$ 15,293
Livestock	
Buy 1,222 good-choice steers, 500 lb., buy Oct. 1 at $24.07 per cwt.	$147,068
Buy 96 tons of cottonseed meal at $75.00 per ton	7,200
Veterinary and medicine, 1,222 head at $1.50 per head per year	1,833
Transportation in for 1,222 steers and out for 1,210 steers = 1,494,300 lbs. at $0.36 per cwt.	5,379
Buy 8 tons alfalfa hay at $25.00 per ton	200
Subtotal	$161,680
Cash fixed costs	
Labor—1 full-time and one seasonal worker ($4,500 per year per full-time man)	$ 6,500
Taxes and insurance (machinery and equipment)	867
Property tax—land and buildings	2,925
Taxes—cattle, $1.50 per head	1,833
Interest—1,216 feeders at $145.00 (8 months). Interest at 6 per cent	7,080
Subtotal	$ 19,205
Depreciation	
Machinery and equipment, fences, buildings	$ 7,306
Interest on investment	
Machinery and equipment, fences, buildings	3,036
Land—4,500 acres at $50.00 per acre = $225,000.00 at 6 per cent	13,500
Subtotal	$ 16,536
NET INCOME	
Net cash income	$ 16,707
Net farm income	$ 9,401
Management income	−$ 7,135

somewhat higher, reaching levels of $9,401 and – $7,135, respectively. Under the conditions specified, the plan does not provide a market rate of return on capital investment.

It should also be noted that the price risk associated with this plan is considerably greater than that for the cow–calf operations discussed earlier.

The reader can readily compute the wide income variation due to prices in this plan by making the desired adjustments in buying and selling prices in the budget in cost-sheet 3. Similar computations can also be made for the other plans presented. A more systematic treatment of decision-making under price uncertainty is considered in the second part of this report.

Plan 4. All-stocker Operation, with 550-pound Steers Bought in January

Plan 4 is another stocker program where steers are not purchased until January 1. This plan cuts down the length of the winter supplemental feeding period. However, the steers available at this time will ordinarily be somewhat heavier and higher priced than those available in October under plan 3. The calves are not sold until a month later (July 1) as compared to plan 3, in order to bring animals to the desired selling weight of about 725 pounds. (The actual buying price is slightly lower in plan 4 than in plan 3 because the 500-pound animals are priced as a simple average of steer calves [300–500 pounds] and stocker and feeder steers [500–800 pounds] in table 3, while the 550-pound animals are priced as entirely stocker and feeder steers [500–800 pounds]. If the prices for the same class of animal are used in both plans, the advantage of plan 3 is increased by about $8,500.)

The text table below shows that under normal range conditions the ranch can support about 1,345 head of stockers. Ranges A and B and most of the barley pasture are used in the spring while clover and barley stubble are reserved for fall feeding.

CATTLE NUMBERS AND ALLOCATION OF FEED SUPPLIES FOR PLAN 4; ALL-STOCKER OPERATION, BUYING 550-POUND STEERS JANUARY 1

CATTLE PROGRAM	HEAD
Good–choice feeders	1,345
PASTURE PROGRAM	**ACRES**
Range A (spring feed)	500
Range B (spring feed)	2,224
Clover (fall feed)	605
Barley	
Grain	233
Hay	121
Stubble (fall feed after grain and hay)	354
Pasture (spring feed)	337
(fall feed)	9
Irrigated pasture (spring and fall)	25

Cost-sheet 4 summarizes costs, returns, and income for plan 4. Although gross income is more than in plan 3, the cost of the stockers also is higher, and the result is that the net income figures are approximately the same as those for plan 3. The plan covers cash expenses and depreciation but leaves only $8,181 as payment toward the operator's management and capital investment.

Range Plus Finishing Operations

The following two plans represent attempts to intensify earlier plans by carrying yearling feeders through a 90-day intensive feeding period to bring them to slaughter weight rather than selling them directly off the range. Plan 5 is the same

COST-SHEET 4. COSTS, RETURNS, AND INCOME FOR PLAN 4; ALL-STOCKER OPERATION, BUYING 550-POUND STEERS JANUARY 1

GROSS INCOME	
Cash receipts	
1,345 good-choice feeder steers, 725 lb., sold July 1 at $23.30 per cwt.	$227,204
3,271 cwt. barley at $1.90 per cwt.	6,215
Subtotal	$223,419
COSTS	
Cash variable costs	
Cultural	
Fertilize 202 acres of clover each year at $4.40 per acre	$ 889
Fertilize 500 acres of Range A every other year at $6.00 per acre	$ 1,500
Fertilize 1,112 acres of Range B every other year at $6.00 per acre	3,336
Produce 233 acres of barley grain at $20.65 per acre	4,811
Produce 121 acres of barley hay at $10.94 per acre	1,324
Prorated cost of establishing 500 acres of clover at $2.50 per acre per year	1,250
Annual costs for 25 acres of irrigated pasture	728
Subtotal	$ 13,838
Livestock	
Buy 1,358 good-choice steers, 550 lb., buy Jan. 1 at $23.29 per cwt.	$173,953
Buy 46 tons of cottonseed meal at $75.00 per ton	3,450
Veterinary and medicine, 1,358 head at $1.50 per head per year	2,037
Transportation in for 1,358 steers and out for 1,345 steers = 1,722,025 lbs. at $0.36 per cwt.	6,199
Buy about 6 tons of alfalfa hay at $25.00 per ton	144
Subtotal	$185,783
Cash fixed costs	
Labor—1 full-time and one summer worker ($4,500 year per full-time man)	$ 6,500
Taxes and insurance (machinery and equipment)	867
Property tax—land and buildings	2,925
Taxes—cattle, $1.50 per head	2,025
Interest—1,350 feeders at $148.00 (6 months). Interest at 6 per cent	5,994
Subtotal	$ 18,311
Depreciation	
Machinery and equipment, fences, buildings	$ 7,306
Interest on investment	
Machinery and equipment, fences, buildings	3,036
Land—4,500 acres at $50.00 per acre = $225,000.00 at 6 per cent	13,500
Subtotal	$ 16,536
NET INCOME	
Net cash income	$ 15,487
Net farm income	$ 8,181
Management income	−$ 8,355

as plan 2 with the additional feeding period, and plan 6 is the same as plan 3 with the additional feeding period. The yearling steers and heifers from these plans are self-fed an intensive barley and supplement finishing ration while confined in fenced range pastures near the ranch headquarters. Table 7 shows that the animals are expected to gain about 2.5 pounds per day during the 90-day period. The cattle are gradually brought onto the high concentrate rations during the latter half of the month preceding the 90-day finishing period, and they reach full feed 45 days later. With this type of finishing program on range it is assumed

TABLE 7

FEED REQUIREMENTS AND DAILY GAINS OF FINISHING STEERS AND HEIFERS WITH HIGH CONCENTRATE RATIONS ON RANGE*

Month	Finishing steers Apr. 15–Aug. 1			Finishing heifers May 15–Sept. 1			Finishing steers May 15–Sept. 1		
	Barley grain	U.C. supplement	Daily gains	Barley grain	U.C. supplement	Daily gains	Barley grain	U.C. supplement	Daily gains
	pounds per day								
April	8	0.8	1.2	...	...	...	...	...	...
May	14	1.6	2.5	8	0.8	1.2	8	0.8	1.2
June	18	2.0	2.5	14	1.6	2.5	14	1.6	2.5
July	18	2.0	2.5	18	2.0	2.5	18	2.0	2.5
August	...	...	...	18	2.0	2.5	18	2.0	2.5
Total for 105 days	1,620	180.0	243.0	1,620	180.0	243.0	1,620	180.0	243.0

* Cattle are put on feed either April 15 or May 15 and reach full feed 45 days later.

that 50 per cent of the animals reach "choice" slaughter grade and the other 50 per cent reach "good" slaughter grade.

Plan 5. Beef Cow Herd, with Calves Sold as Slaughter Steers and Heifers

Cost-sheet 5 summarizes costs, returns, and net income measures for a 312 beef cow herd, in which calves are finished as described above. The beef cow herd operation and the pasture utilization is identical with that in plan 2, hence this plan represents an attempt to intensify the range operation by converting most of the barley produced in plan 2 into finished beef. However, gross and net incomes increase only moderately from plan 2 to plan 5. A comparison of cost-sheets 2 and 5 shows that gross income is increased by only about $6,500, and the various net income measures by only about $3,000. Undoubtedly, price risk also increases with the intensive feeding program.

Plan 6. All-stocker Operation, with Stockers Sold as Slaughter Steers

Cost-sheet 6 (plan 6) shows incomes resulting from addition of a finishing period to the all-stocker plan 3, where 500-pound steers are bought October 1. This plan represents a method of greatly increasing the volume of sales of the range operation. However, it represents an increasing dependence on the market, not only for cattle but for purchased feed. All of the previous plans included sufficient barley production to satisfy feed requirements and leave a surplus for cash sale, but plan 6 requires almost $35,000 worth of barley to carry the yearlings to finished weight.

Cost-sheet 6 shows that plan 6 produces a sizable increase in net incomes over the previous plans. Under the assumptions employed, the plan produces sufficient income to cover all cash costs, depreciation, a market rate of interest on the investment, and to leave a manage-

Cost-Sheet 5. COSTS, RETURNS, AND INCOME FOR PLAN 5: 312-HEAD BEEF COW HERD, WITH CALVES SOLD AS SLAUGHTER STEERS AND HEIFERS

GROSS INCOME	
Cash receipts	
4 bulls, 1,500 lb., sold at $20.00 per cwt.	$ 1,200
28 utility cows, 1,000 lb., sold Feb. 1 at $15.64 per cwt.	4,379
6 utility cows, 1,000 lb., sold Apr. 1 at $16.54 per cwt.	992
19 utility cows, 1,000 lb., sold Sept. 1 at $15.50 per cwt.	2,945
136 good-choice slaughter steers, 936 lb., sold Aug. 1 at $24.42 per cwt.	31,086
71 good-choice slaughter heifers, 900 lb., sold Sept. 1 at $22.73 per cwt.	14,524
312 cwt. barley at $1.90 per cwt.	593
Subtotal	$55,719
Cash variable costs	
Cultural	
Fertilize 202 acres of clover each year at $4.40 per acre	$ 889
Fertilize 500 acres of Range A every other year at $6.00 per acre	1,500
Fertilize 1,112 acres of Range B every other year at $6.00 per acre	3,336
Produce 233 acres of barley grain at $20.65 per acre	4,811
Produce 176 acres of barley hay at $10.94 per acre	1,925
Prorated cost of establishing 500 acres of clover at $2.50 per acre per year	1,250
Annual cost for 25 acres of irrigated pasture	728
Subtotal	$14,439
Livestock	
Veterinary and medicine, 312-cow herd at $1.50 per head per year, 207 yearlings and finished cattle at $1.50 per head per year	$ 778
Buy 4 replacement bulls at $500.00 per head	2,000
Buy 94 tons of cottonseed meal at $75.00 per ton	7,050
Buy salt ($30.00 per 100 cows)	94
Buy 373 cwt. of U. C. supplement at $2.90 per cwt.	1,082
Transportation out for 53 cull cows, 207 slaughter steers and heifers and in and out for 4 bulls = 256,196 lbs. at $0.36 per cwt.	922
Buy 6 tons alfalfa hay at $25.00 per ton	150
Subtotal	$12,076
Cash fixed costs	
Labor—1 full-time and two seasonal workers ($4,500 per year per full-time man)	$ 8,500
Taxes and insurance (machinery and equipment)	867
Property tax—land and buildings	2,925
Taxes—cattle, $1.80 per cow, bull, or heifer replacement, $0.35 calf; $1.00 for finished steers	931
Interest—337 cows and heifers at $150 (year); 275 calves at $100.00 (year); 207 yearling finished steers at $160.00 (8 months); 12 bulls at $500.00 (year); interest at 6 per cent	6,372
Subtotal	$19,595
Depreciation	
Machinery and equipment, fences, buildings	$ 7,306
Interest on investment	
Machinery and equipment, fences, buildings	3,036
Land—4,500 acres at $50.00 per acre = $225,000 at 6 per cent	13,500
Subtotal	$16,536
NET INCOME	
Net cash income	$10,531
Net farm income	$ 3,225
Management income	−$13,311

ment income of $3,156. As noted, the increasing dependence on buying and selling involves an obvious increase in risk and managerial responsibility over the previous plans. This risk factor is analyzed in more detail, starting on page 22.

Cost-Sheet 6. COSTS, RETURNS, AND INCOME FOR PLAN 6; ALL-STOCKER OPERATION, WITH 500-POUND STEERS BOUGHT OCTOBER 1 AND SOLD AS SLAUGHTER STEERS

GROSS INCOME	
Cash receipts	
1,205 good-choice slaughter steers, 945 lb., sold Sept. 1 at $24.06	$273,977
COSTS	
Cash variable costs	
Cultural	
Fertilize 202 acres of clover each year at $4.40 per acre	$ 889
Fertilize 500 acres of Range A every other year at $6.00 per acre	1,500
Fertilize 1,112 acres of Range B every other year at $6.00 per acre	3,336
Produce 233 acres of barley grain at $20.65 per acre	4,811
Produce 254 acres of barley hay at $10.94 per acre	2,779
Prorated cost of establishing 500 acres of clover at $2.50 per acre per year	1,250
Annual costs for 25 acres of irrigated pasture	728
Subtotal	$15,293
Livestock	
Buy 1,222 good-choice steers, 500 lb., buy Oct. 1 at $24.07 per cwt.	$147,068
Buy 17,236 cwt. of barley at $2.00 per cwt.	34,472
Buy 123 tons of cottonseed meal at $75.00 per ton	9,225
Buy 108 tons of U. C. supplement at $58.00 per ton	6,264
Veterinary and medicine, $2.00 per head for 1,210 steers	2,420
Transportation in for 1,222 steers and out for 1,205 steers = 1,749,725 lbs. at $0.36 per cwt.	6,299
Buy 8 tons alfalfa hay at $25.00 per ton	200
Subtotal	$205,948
Cash fixed costs	
Labor—1 full-time and two seasonal workers ($4,500.00 per year per full-time man)	$ 8,500
Taxes and insurance (machinery and equipment)	867
Property tax—land and buildings	2,925
Taxes—cattle, $1.50 per head for steers	1,808
Interest—1,210 steers at $175.00 (11 months). Interest at 6 per cent	11,638
Subtotal	$ 25,738
Depreciation	
Machinery and equipment, fences, buildings	$ 7,306
Interest on investment	
Machinery and equipment, fences, buildings	3,036
Land—4,500 acres at $50.00 per acre = $225,000 at 6 per cent	13,500
Subtotal	$ 16,536
NET INCOME	
Net cash income	$ 26,978
Net farm income	$ 19,692
Management income	$ 3,156

II. OPTIMUM PLANS FOR UNCERTAIN PRICES AND RANGE CONDITIONS

Part I of this report determined the income levels possible from six alternative livestock plans. The simplifying assumption was made throughout that the net incomes shown were those possible during years of normal or average range conditions and prices. Part II of this report attempts to deal more realistically with the question: "Given the uncertainty or variability of range conditions and prices from year to year, what are the most profitable stocking rates?" Many ranchers appear to stock their range land on the assumption that normal range conditions will occur. Then, if conditions improve, they adjust by buying more cattle or by holding the normal number of cattle for a longer period of time. If conditions worsen, they sell some cattle or buy hay to supplement those already purchased. However, it might be more profitable to stock the range well above or below normal, once again using the option of adjusting numbers to different range conditions as they arise. For example, it might be more profitable in the long run to regularly overstock the range and sell off some animals as range conditions develop than to be "caught short" with normal numbers when an excellent range year occurs.

Similar questions can be raised about the best strategy of buying and selling calves or feeders given the uncertainty of cattles prices. Both types of questions will be analyzed here by means of statistical decision theory.

The essential element of statistical decision theory is that the relative frequencies (probabilities) of every range or price eventuality must be determined. For example, if range conditions were divided into three basic categories—poor, average, and excellent—it would be necessary to determine the probability that each would occur. If poor range conditions occurred 25 per cent of the time, average conditions 40 per cent of the time, and excellent conditions 35 per cent of the time (total = 100 per cent), the probabilities would be 0.25, 0.40, and 0.35. These probabilities often would be determined objectively based on historical data. Lacking the necessary data, the rancher might estimate these subjectively on his own experience or intuition. Once these probabilities are determined, they are used as weights in determining the weighted average net income for each stocking rate to be considered. That stocking rate which gives the highest weighted average net income is selected as the best strategy for the long run. However, some ranchers may wish to select a different strategy because they are not in a position to take a long-run point of view. For example, a rancher near bankruptcy may select a very safe strategy with a low average income, rather than one which provides a high average income with so much variability that it may cause him financial ruin if a bad year should occur.

In plans where price uncertainty is important, probabilities are determined for each possible price and the optimum long-run plan selected on the basis of the highest weighted average net income. In some plans, both price and weather uncertainty play a key role. Hence, the probabilities of various combinations of price and range conditions (joint probabilities) are determined and the decision made which takes into account both of these sources of variability in the same problem.

The probabilities used in this study are based on historical published data on range and price conditions. Information on range conditions for the Sacramento

TABLE 8

FREQUENCIES OF VARIOUS RANGE CONDITIONS, SACRAMENTO VALLEY, 1922–1963

Average range condition, February 1–June 1		Relative frequencies		
Description	Range index interval	Number of years observed	Percentage of years	Probabilities*
Very poor	Less than 55	2	4.8	0.048
Poor	55 to 64.9	5	11.9	0.119
Fair	65 to 74.9	8	19.0	0.190
Normal	75 to 84.9	13	31.0	0.310
Good	85 to 94.9	11	26.2	0.262
Excellent	95 or over	3	7.1	0.071
Total	.....	42	100.0	1.000

* These are the *a priori* probabilities discussed in Appendix B.
SOURCE: Data in Appendix table A-1.

Valley is available in the form of monthly range condition indexes published by the California Department of Agriculture (see Appendix table A-1). These indexes should be a good indication of actual conditions on the study ranch. An important assumption in computing the plans and incomes of Part II is that the actual feed supply in any year is proportional to the range index observed. An average range condition of 78 was computed for the grazing period (February 1–June 1), based on data from 1922–63. The normal feed supply used in Part I was specified as equal to a range index of 78. If the range index was, for example, 20 per cent above normal (= 94), it was assumed that the feed supply in animal unit months also increased proportionately (by 20 per cent). Likewise, if the range index was (say) 20 per cent below normal (= 62), the feed supply was assumed to decrease by 20 per cent. The assumption that range feed supply is roughly proportionate to the range index was compared with earlier studies (Bentley and Talbot, 1951) which reported variation of from 1,200 to 2,350 pounds of air dry herbage per grazable acre (average = 1,640 pounds) over the 13-year period 1935–36 to 1947–48. Using 78 as the mean range index, this would imply variation in the range index of 57 to 111, which approximates the variation actually recorded (Appendix table A-1). Appendix table A-1 confirms the common knowledge that range conditions are extremely variable within and among years.

Table 8 summarizes the frequencies with which various range conditions have been observed over the 42-year period 1922–63 in the Sacramento Valley. The last two columns convert these data to percentages and then to the probabilities used throughout part II.

Table 9 summarizes the frequencies with which various price margins between 500–800 pound feeder cattle prices in June and 900–1,100 pound slaughter steers in September have occurred from 1925 to 1963, adjusted to the Stockton market.[3] These frequencies (probabilities) will be used in evaluating the de-

[3] Stockton prices are reported only for 1952–63, an insufficient time to obtain realistic probabilities. Therefore, price margins were calculated between Kansas City feeder prices and Chicago slaughter prices for 1925–63. These were adjusted to reflect Calfiornia conditions by computing the average absolute difference in price margins between the Stockton and Kansas City–Chicago markets from 1952–63. This constant was then added to the 1925–51 Kansas City–Chicago margins to obtain an approximation to Stockton conditions during those years.

TABLE 9

FREQUENCIES OF PRICE MARGINS BETWEEN 500–800-POUND GOOD AND CHOICE FEEDER CATTLE PRICES IN JUNE, AND 900–1,100-POUND GOOD AND CHOICE SLAUGHTER STEERS IN SEPTEMBER, 1925–1963*

Price margin, June 1–September 1		Relative frequencies		
Range	Average	Number of years observed	Percentage of years	Probabilities‡
dollars per hundredweight				
−2.50 to −1.51†	−2.00	2	5.1	0.051
−1.50 to −0.51	−1.00	5	12.7	0.127
−0.50 to 0.49	0.00	9	23.1	0.231
0.50 to 1.49	1.00	15	38.5	0.385
1.50 to 2.49	2.00	6	15.4	0.154
2.50 to 3.49	3.00	1	2.6	0.026
3.50 to 4.49	4.00	1	2.6	0.026
Total	....	39	100.0	1.000

* Adjustment to Stockton price margin from Kansas City-Chicago price margin.
† Negative numbers refer to a price drop between June 1 and September 1.
‡ Used both as *a priori* and *a posteriori* probabilities (as discussed in Appendix B).
SOURCE: Data in Appendix table A-2.

cision of whether to sell feeders in June or carry them through a finishing period for sale in September (plan 6).

Table 10 shows the frequencies with which various October–June price margins of stockers and feeders have occurred from 1925 to 1962, adjusted to the Stockton market. These frequencies will be used in the decision of optimum stocking rate for stockers on range when both range and price variability are considered (plan 3).

The first major section of Part II deals with uncertainty due to range conditions alone, with prices held constant. This analysis is applied to the strictly range cow herd and feeder operations (plans 1–4) of Part I, as adjustment to variable range conditions is the major decision to be made in such plans.

The second major section of Part II deals with uncertainty due to prices. Price uncertainty is important to decision-making primarily in plans 5–6 where the question is whether or not to finish out the feeders coming off range by feeding them intensively throughout summer. Plan 6 appeared to be more profitable and more promising than plan 5 in Part I, hence only plan 6 is analyzed in some detail under price uncertainty. In effect, plan 6 involves two major decisions: (1) the decision on stocking rates of stockers to go on range, which depends primarily on range conditions (same as plan 3 analyzed above), and (2) the decision on whether or not to feed out those animals to slaughter weight, which depends on price relations. Hence, plan 6 involves both range and price uncertainty but with each handled independently at different points in time.

The third major section of Part II deals briefly with the question of considering price and range variability simultaneously; i.e., joint uncertainty of prices and range conditions. This approach is applied to the question of the optimum stocking rate for the all-stocker operation in plan 3.

A final section of Part II summarizes the improvements in average net income which were obtained by using the decision theory of Part II to revise the decisions made in Part I, which relied on assumed normal conditions.

TABLE 10

FREQUENCIES OF OCTOBER-JUNE PRICE MARGINS OF STOCKERS AND FEEDERS, ADJUSTED TO 500–800-POUND GOOD AND CHOICE STOCKERS AND FEEDERS AT STOCKTON, 1925–1962*

Price margin, October 1–June 1		Relative frequencies		
Range	Average	Number of years observed	Percentage of years	Probabilities‡
dollars per hundredweight				
Less than −1.50†	−3.00	4	10.5	0.105
−1.50 to 0.51	−1.00	2	5.4	0.054
−0.50 to 0.49	0.00	8	21.0	0.210
0.50 to 1.49	1.00	8	21.0	0.210
1.50 to 2.49	2.00	6	15.8	0.158
2.50 to 3.49	3.00	4	10.5	0.105
3.50 or over	5.00	6	15.8	0.158
Total	....	38	100.0	1.000

* Adjustment to Stockton price margin from Kansas City price margin.
† Negative numbers refer to a price drop between Oct. 1 and June 1.
‡ Used both as *a priori* and *a posteriori* probabilities as discussed in Appendix B.
SOURCE: Data in Appendix table A-2.

Uncertainty Due to Range Conditions

Plan 1. Beef Cow Herd, Calves Sold as Weaners

The problem here is to determine the optimum size of beef cow herd (calves sold as weaners) under uncertainty of range conditions. Two types of errors are possible: if the herd is too large, the cost of supplemental feeding in poor range years will be high; if the herd is too small, large amount of feeds go unutilized. The objective is to find the herd size which maximizes the weighted average or expected profit (or minimizes expected losses) in the long run. For a cow-calf operation, the uncertainty due to range conditions is of primary importance for decision making.

Six possible herd sizes ranging from 231 to 462 head are considered as the alternatives available. These herd sizes were selected to correspond to the six levels of range conditions; 231 cows is the size of herd which approximately utilizes the feed supply available under very poor range conditions; 360 cows (the herd size in part I) corresponds to feed supplies available under normal range conditions.

Table 11 shows the net incomes associated with each alternative herd size and range condition for plan 1. The net incomes are derived for each cell in table 11 by using plan 1 (Part I) as the basis, and then adjusting to the corresponding cattle numbers and the cost of meeting the feed deficits. The calculated feed deficits (in AUM's) for each cell are shown in parentheses under the net income figure. These feed deficits (and those in following tables) represent the minimum deficits possible when the optimum amount of pasture is allocated to spring and fall grazing. (In some cases, this allocation was sufficiently complex to require additional linear programming solutions. In plan 1 the over-all deficit is minimized by shifting part of the range A and B land from fall to spring grazing where it has a higher feed value—see table 1.) If a large herd is used and range conditions are poor, feed deficits

TABLE 11

NET INCOMES AND FEED DEFICITS FOR PLAN 1 FOR VARIOUS RANGE CONDITIONS

Range condition	Herd size, net income, and feed deficits*						Probabilities
	231 head	277 head	323 head	360 head	415 head	462 head	
Very poor	−$5,347 (45)	−$7,063 (506)	−$9,029 (992)	−$10,807 (1,403)	−$13,460 (2,014)	−$15,704 (2,536)	0.048
Poor	− 4,097 (0)	− 1,643 (52)	− 2,859 (513)	− 4,737 (884)	− 7,390 (1,495)	− 9,634 (2,017)	0.119
Fair	− 3,297 (0)	− 323 (0)	2,061 (59)	− 673 (431)	− 1,370 (981)	− 3,574 (1,499)	0.190
Normal	− 2,657 (0)	317 (0)	3,291 (0)	5,027 (66)	4,764 (438)	1,250 (1,087)	0.310
Good	− 1,697 (0)	1,277 (0)	4,251 (0)	6,647 (0)	9,460 (74)	7,736 (544)	0.262
Excellent	− 897 (0)	2,077 (0)	5,051 (0)	7,447 (0)	11,000 (0)	13,156 (90)	0.071
Weighted average net income†	−$2,701	−$12	$2,116	$2,879	*$2,957*	$778	1.000

* Figures in parentheses are feed deficits (in AUM's). Other figures are net incomes. Negative numbers represent negative net incomes (losses).

† Highest weighted average net income in italics indicates optimum herd size.

are large and supplementary feed costs are very high. (The cost of each AUM deficit is $10, based on 1 AUM = 0.4 tons of alfalfa hay at $25 per ton.) On the other hand, if a small herd is used and range conditions are favorable, feed goes to waste (the deficits are zero) and opportunities for additional profits are foregone.

The long-run weighted average (expected) net income for a particular herd size is found by weighting the net incomes in that column by the respective probabilities (shown in the right-hand column) that each range condition will occur. For example, the weighted average net income for a 231-head cow herd (first column) is computed as follows: − $5,347 (0.048) − $4,097 (0.119) − $3,297 (0.190) − $2,657 (0.310) − $1,697 (0.262) − $897 (0.071) = − $2,701.

Table 11 also shows that a cow herd of 415 head provides a weighted average income of $2,957. This stocking rate is somewhat above the 360-cow herd developed for normal range conditions in Part I. In other words, it pays to stock at a rate above normal and supplement the cows in years of normal or below-normal range conditions. However, table 11 shows that the expected income advantage of a 415-head cow herd over a 360 cow herd is only $78—hardly incentive enough to shift away from the normal stocking rate.

Plan 2. Beef Cow Herd, Calves Sold as Yearlings

This plan is similar to plan 1 except that the calves are not sold as weaners in the fall but are retained through fall and winter. They are sold about May 1, at 16 months of age, with the steers weighing 720 pounds and the heifers 650 pounds. Assumptions about variability of range conditions and forage production are the same as those used in plan 1. Due

TABLE 12

NET INCOMES AND FEED DEFICITS FOR PLAN 2 FOR VARIOUS RANGE CONDITIONS

Range condition	Herd size, net income, and feed deficits*						Probabilities
	200 head	240 head	280 head	312 head	360 head	400 head	
Very poor	−$5,314 (51)	−$7,004 (506)	−$9,254 (1,017)	−$11,083 (1,425)	−$13,734 (2,037)	−$15,984 (2,548)	0.048
Poor	− 3,902 (0)	− 1,561 (61)	− 3,261 (517)	− 4,943 (914)	− 7,631 (1,526)	− 9,881 (2,037)	0.119
Fair	− 2,999 (0)	− 49 (0)	2,751 (15)	1,399 (379)	− 969 (959)	− 3,219 (1,470)	0.190
Normal	− 2,277 (0)	673 (0)	3,624 (0)	5,834 (15)	3,806 (561)	1,746 (1,053)	0.310
Good	− 1,194 (0)	1,756 (0)	4,706 (0)	7,067 (0)	10,427 (18)	8,727 (474)	0.262
Excellent	− 291 (0)	2,659 (0)	5,609 (0)	7,969 (0)	11,510 (0)	14,260 (20)	0.071
Weighted average net income†	−$2,326	$ 330	$2,451	*$ 3,379*	$ 2,985	$ 1,295	1.000

* Figures in parentheses are feed deficits (in AUM's). Other figures are net incomes. Negative numbers represent negative net incomes (losses).

† Highest weighted average net income in italics indicates optimum herd size.

to the increased feed requirements of the calves, however, the sizes of cow herds considered must be reduced compared with plan 1.

Table 12 gives the AUM deficits and the net farm incomes associated with each herd size and range condition for plan 2. Weighting the net incomes for each herd size by the probabilities of the various range conditions gives the expected net farm income for each herd size. (Net farm income figures for these calculations do not include interest on cattle or calves.) For this program the optimum herd size is the "normal" number of 312 cows. The expected net return for this alternative is $3,379.

A variation of plans 1 and 2, suggested by the work of Bentley and Talbot (1951), is to stock the range with a cow herd somewhat smaller than that required to consume the feed supply in a normal range year. Then, if range production is below normal the calves are sold in the fall and early winter as weaners; if range conditions are above normal, the calves can be carried through the winter and sold as yearlings in the spring. This alternative is not developed in detail here because preliminary analysis showed little promise of substantially raising the income level by combinations of plans with such a low volume of business.

Bentley and Talbot (1951) also mention the possibility of utilizing a smaller cow herd than desirable under normal range conditions and meeting the forage fluctuations from year to year by bringing in outside animals, such as stocker steers. Table 13 shows the net income data and the feed deficits for six alternative sizes of cow herds (200 to 400 head), each with various numbers of 550-pound stocker steers purchased in January. Applying the probabilities of various range conditions to each stocking alternative, it is found that the highest weighted average net income ($6,104)

TABLE 13

NET INCOMES AND FEED DEFICITS FOR COMBINATIONS OF COW HERD PLUS SUPPLEMENTAL STOCKER STEERS*

Range condition	Herd size, net income, and feed deficits*											Probability
	200 cows plus:						240 cows plus:					
	0 steers	163 steers	356 steers	484 steers	685 steers	854 steers	0 steers	176 steers	319 steers	520 steers	689 steers	
Very poor	−$ 5,314 (51)	−$ 6,766 (496)	−$ 8,125 (1,094)	−$ 9,610 (1,491)	−$11,382 (2,113)	−$12,912 (2,638)	−$ 7,004 (506)	−$ 8,589 (520)	−$ 9,792 (963)	−$11,564 (1,586)	−$13,104 (2,110)	0.048
Poor	− 3,902 (0)	− 658 (0)	− 1,210 (589)	− 2,819 (986)	− 4,730 (1,609)	− 6,269 (2,133)	− 1,561 (61)	− 3,146 (520)	− 4,349 (963)	− 6,122 (1,586)	− 7,661 (2,110)	0.119
Fair	− 2,999 (0)	244 (0)	4,441 (0)	4,435 (388)	3,319 (1,011)	1,344 (1,533)	− 49 (0)	3,432 (0)	2,918 (417)	1,410 (1,040)	− 338 (1,564)	0.190
Normal	− 2,277 (0)	967 (0)	5,163 (0)	7,369 (0)	7,611 (614)	5,339 (1,138)	673 (0)	4,155 (0)	7,072 (0)	6,610 (597)	5,546 (1,121)	0.310
Good	− 1,194 (0)	2,049 (0)	6,246 (0)	8,450 (0)	12,466 (0)	10,158 (515)	1,756 (0)	5,238 (0)	8,154 (0)	12,170 (0)	10,319 (498)	0.262
Excellent	− 291 (0)	2,952 (0)	7,148 (0)	9,353 (0)	13,369 (0)	16,701 (0)	2,659 (0)	6,140 (0)	9,057 (0)	13,073 (0)	16,405 (0)	0.017
Weighted average net income†	−$ 2,327	$ 693	$ 4,060	$ 5,124	**$ 6,104**	$ 4,401	−$ 330	$ 2,967	$ 4,544	*$ 5,157*	$ 3,991	1.000
	280 cows plus:				312 cows plus:			360 cows plus:		400 cows		
	0 steers	139 steers	352 steers	524 steers	0 steers	208 steers	391 steers	0 steers	174 steers	0 steers		
Very poor	−$ 9,254 (1,017)	−$10,425 (386)	−$12,424 (1,046)	−$13,846 (1,579)	−$11,038 (1,425)	−$12,866 (608)	−$14,496 (1,175)	−$13,734 (2,037)	−$15,303 (483)	−$15,984 (2,548)		0.048
Poor	− 3,261 (517)	− 4,432 (386)	− 6,431 (1,046)	− 7,853 (1,579)	− 4,943 (914)	− 6,771 (608)	− 8,402 (1,175)	− 7,631 (1,526)	− 9,201 (483)	− 9,881 (2,037)		0.119
Fair	2,751 (15)	1,580 (386)	− 418 (1,046)	− 1,840 (1,579)	1,399 (379)	− 429 (608)	− 2.059 (1,175)	− 969 (959)	− 2,538 (483)	− 3,219 (1,470)		0 190
Normal	3,624 (0)	6,456 (0)	5,538 (615)	3,864 (1,149)	5,834 (15)	4,006 (608)	2,376 (1,175)	3,806 (561)	2,237 (483)	1,746 (1,053)		0.310
Good	4,706 (0)	7,538 (0)	11,669 (0)	11,965 (488)	7,067 (0)	11,232 (0)	10,472 (530)	10,427 (18)	8,858 (483)	8,727 (474)		0.262
Excellent	5,609 (0)	8,441 (0)	12,572 (0)	16,109 (0)	7,969 (0)	12,135 (0)	15,767 (0)	11,510 (0)	14,948 (0)	14,260 (20)		0.017
Weighted average net income	$ 2,451	$ 3,853	*$ 4,214*	$ 3,536	$ 3,379	*$ 3,549*	$ 2,522	*$ 2,985*	$ 1,773	*$ 1,294*		1.000

* Figures in parentheses are feed deficits (in AUM's). Other figures are net incomes. Negative numbers represent negative net income (losses).
† Highest weighted average net income for each size of cow herd is shown in italic. Highest weighted average net income for all herd sizes are bold figures.

results from a minimum-sized cow herd of 200 head, plus 685 supplemental stocker steers. Selection of this alternative shows that it pays to slightly overstock the range with stockers compared with normal range conditions and to feed some supplemental feed in most years, rather than understocking to avoid supplemental feeding.

The operator will probably not buy the same number of supplemental steers each year as assumed in table 13, but will instead try to adjust the number of steers purchased to the range conditions of the year. By January, when steers are purchased, the operator will have some idea of whether range conditions during that year will be favorable or unfavorable—an opinion based on rainfall, temperature, and range conditions up to that date. Let us assume that the operator observes from historical data, or from personal experience, the degree of correspondence between the range condition which exists on the first of January and the subsequent spring range condition. Or let us assume that he computes the probabilities that each of the various range conditions will follow a particular observed range condition on January 1. For example, given a fair range condition on January 1, he determines the probabilities that the true range condition will turn out to be very poor, poor, fair, normal, good, and excellent (see Appendix table A-6). These revised probabilities then become the weights used in calculating the weighted average net income for each stocking rate, given the particular range condition observed January 1 (table 14). The results show that, in general, the optimum size of cow herd is the minimum of 200 head. However, the optimum number of supplemental stockers to buy depends on the range condition on January 1. If there are very poor conditions, stock 484 steers;[4] if poor conditions, stock 356 steers; if fair, normal, or good conditions, stock 685 steers; if excellent conditions, stock 854 steers.

To what extent has the revision of probabilities based on the observed range condition on January 1 improved the weighted average net income in the long run? It is calculated that this improvement averages only $262 per year.[5] The apparent conclusion is that the actual January 1 range condition is not a sufficiently accurate predictor of the following range conditions in winter and spring to be very useful in adjusting stocking rates. However, further analysis of table 14 shows that even if a perfect predictor were available the total improvement in average net income would be only $566.

Plan 3. All-stocker Operation, with 500-pound Steers Bought in October

Under this plan 500-pound steers are bought about October 1, kept through winter and spring, and sold about June 1. As with plans 1 and 2, the decision to buy is made long before spring range conditions are known. Available stocking rates vary from 756 to 1,512 head, corresponding to the numbers of stockers which approximately consume the green feed available for the different levels of range conditions (i.e., 756 head approximately use the green feed available with very poor range conditions, etc.).

The first case considered is one in which the rancher keeps stockers until June 1, regardless of the actual range condition; this often requires a substantial amount of hay feeding toward the

[4] The stocking rate of 484 may be high due to the limited number of observations under very poor range conditions on January 1 and, therefore, a computed 0.5 probability of normal spring range conditions, given very poor range conditions on January 1 (see table A-6).

[5] Technically, this means that the expected net income for the *data* problem (table 14) is $6,366 and only $6,104 for the *no data* problem (table 13). Thus, *the value of the experiment* is only $6,366 – $6,104 = $262. The *value of the experiment* for a perfect prediction device would be only $566.

TABLE 14

NET INCOMES FOR COMBINATIONS OF COW HERD PLUS SUPPLEMENTAL STOCKER STEERS, AND RANGE CONDITIONS, USING PROBABILITIES REVISED ON BASIS OF RANGE CONDITIONS ON JANUARY 1*

Observed January 1 range condition	Herd size and expected net income†										
	200 cows plus:						240 cows plus:				
	0 steers	163 steers	356 steers	484 steers	685 steers	854 steers	0 steers	176 steers	319 steers	520 steers	689 steers
Very poor	−$3,796	−$3,900	−$1,481	**−$1,121**	−$1,886	−$3,786	−$3,166	−$2,217	*−$1,360*	−$2,477	−$3,779
Poor	− 3,276	− 554	**1,442**	1,229	496	− 1,354	− 1,044	*185*	127	− 768	− 2,359
Fair	− 2,458	786	4,033	5,254	**5,685**	3,582	371	2,839	4,589	*4,656*	3,271
Normal	− 2,349	893	5,091	6,411	**6,865**	4,705	601	4,082	5,627	*5,642*	4,147
Good	− 1,234	2,009	6,206	8,410	**11,588**	10,541	1,716	5,198	8,114	*11,135*	10,611
Excellent	− 742	2,500	6,697	8,902	12,918	*13,430*	2,208	5,689	8,606	12,622	*13,362*
	280 cows plus:				312 cows plus:			360 cows plus:		400 cows	
	0 steers	139 steers	352 steers	524 steers	0 steers	208 steers	391 steers	0 steers	174 steers	0 steers	
Very Poor	−$2,815	*−$1,984*	−$3,443	−$4,991	*−$2,602*	−$4,430	−$6,060	*−$4,964*	−$6,533	*−$7,119*	
Poor	− *272*	− 554	− 1,751	− 3,010	− *974*	− 2,136	− 3,669	− *2,810*	− 4,380	− *4,978*	
Fair	2,376	*4,007*	3,775	2,570	*3,482*	2,852	1,396	*2,365*	796	*320*	
Normal	3,491	*4,722*	4,382	3,203	*4,307*	3,677	2,221	*3,220*	1,651	*1,156*	
Good	4,666	7,498	10,507	*11,086*	6,993	9,827	*9,850*	*9,196*	8,740	*8,405*	
Excellent	5,158	7,990	12,120	**14,037**	7,518	11,684	*13,120*	10,968	*11,903*	*11,494*	

* Revised probabilities technically are *a posteriori* probabilities calculated in Appendix table A-6.

† Italic net income figures indicate, given the January 1 range condition and basic size of cow herd, the optimum number of supplemental stockers; bold net income figures indicate, given the January 1 range condition, the optimum size of cow herd and number of supplemental stockers.

TABLE 15

NET INCOMES AND FEED DEFICITS FOR PLAN 3 FOR VARIOUS RANGE CONDITIONS

Range condition	Stocking rate, net income, and feed deficits*						Probabilities
	756 head	908 head	1,059 head	1,210 head	1,361 head	1,512 head	
Very poor	−$3,535 (5)	−$4,404 (392)	−$5,418 (777)	−$6,319 (1,163)	−$8.186 (1,631)	−$9,877 (2,099)	0.048
Poor	− 2,219 (0)	832 (7)	− 182 (392)	− 1,083 (778)	− 2,950 (1,246)	− 4,641 (1,714)	0.119
Fair	− 959 (0)	2,170 (0)	5.044 (8)	4,143 (394)	2,276 (882)	557 (1,330)	0.190
Normal	321 (0)	3,450 (0)	6,414 (0)	9,401 (9)	7,534 (477)	5,843 (945)	0.310
Good	1,601 (0)	4,730 (0)	7,694 (0)	10,781 (0)	12,792 (92)	11,101 (560)	0.262
Excellent	2,861 (0)	5,990 (0)	8,954 (0)	11,841 (0)	14,984 (83)	16,327 (176)	0.071
Weighted average net income†	$ 108	$3,037	$5,321	*$6,939*	$6,445	$4,965	1.000

* Figures in parentheses are feed deficits (in AUM's); other figures are net incomes. Negative numbers represent negative net incomes (losses).

† Highest weighted average net income in italics indicates optimum stocking rate.

end of the period, as shown by the feed deficits in table 15. The weighted average net incomes show 1,210 head to be the optimum stocking rate in this case, corresponding to the stocking rate for normal conditions.

A second and perhaps more realistic case considered under this plan is when the rancher sells the cattle as soon as range feed supples are exhausted. However, it is assumed that the rancher will keep the animals on range for a minmum of 45 days (until April 1), selling after this date when the feed runs out. Although this situation reduces the feed deficit which might occur in poor range years, it also means that the rancher will often sell the cattle at lighter weights. The net farm incomes for the various stocking rates and range conditions are given in table 16. The optimum stocking rate has now shifted upward to 1,361 head. This is higher than the normal rate, and offers an expected net farm income of $8,034—an improvement of $1,095 over basic plan 3, where the calves are carried to June 1 regardless of range conditions. Thus an operator should take advantage of the increased profit permitted by this added flexibility, rather than adhering to a rigid selling date regardless of feed conditions.

Plan 4. All-stocker Operation, with 550-pound Steers Bought in January

Under plan 4, stockers are not purchased until January 1 and are purchased at a heavier weight. The stockers are kept a month later (July 1) as compared to plan 3 to bring them to the desired selling weight (725 pounds). One advantage of buying in January, rather than earlier, is that the rancher has by this time a better indication of the actual spring range conditions and can adjust his cattle numbers accordingly. Using the January 1 range condition report as an observation or indicator, the revised probabilities

TABLE 16

NET INCOMES FOR PLAN 3 FOR VARIOUS RANGE CONDITIONS; CATTLE SOLD WHEN FEED SUPPLIES EXHAUSTED

Range condition	Stocking rates and net incomes*						Probabilities
	756 head	908 head	1,059 head	1,210 head	1,361 head	1,512 head	
Very poor	−$3,535	−$4,525	−$4,103	−$3,326	−$4,685	−$6,012	0.048
Poor	− 2,219	832	1,267	460	906	− 313	0.119
Fair	− 959	2,170	5,044	6,188	4,011	5,026	0.190
Normal	321	3,450	6,414	7,401	9,578	7,972	0.310
Good	1,602	4,730	7,694	10,781	12,792	13,646	0.262
Excellent	2,861	5,990	8,954	11,841	14,984	16,327	0.071
Weighted average net income†	$ 108	$3,027	$5,557	$7,655	*$8,034*	$7,842	1.000

* Negative numbers represent negative net incomes (losses).
† Highest weighted average net income in italic indicates optimum stocking rate.

of Appendix table A-6 are again used in developing the most profitable stocking rate strategy.

In the first situation considered, the rancher keeps the steers until July 1, regardless of the range condition which develops in the spring. After adjusting the basic budget for plan 4 in Part I (cost sheet 4) for changes in cattle numbers and feed deficits, the net incomes and feed deficits for each alternative are as shown in table 17. Disregarding the January 1 range condition and considering only the long-run probabilities of the various range conditions, the optimum long-run stocking rate is 1,345 head (corresponding to normal range conditions), which returns a long-run average net in-

TABLE 17

NET INCOMES AND FEED DEFICITS FOR PLAN 4 FOR VARIOUS RANGE CONDITIONS

Range condition	Stocking rates, net income, and feed deficits*						Probabilities
	841 head	1,009 head	1,177 head	1,345 head	1,513 head	1,681 head	
Very poor	−$3,691 (139)	−$5,585 (534)	−$7,575 (1,048)	−$9,411 (1,569)	−$11,395 (2,090)	−$13,307 (2,610)	0.048
Poor	− 3,007 (0)	237 (173)	− 1,753 (568)	− 3,589 (1,055)	5,575 (1,576)	− 7,485 (2,096)	0.119
Fair	− 2,407 (0)	969 (0)	4,147 (197)	2,311 (592)	327 (1,052)	− 1,585 (1,572)	0.190
Normal	− 1,807 (0)	1,569 (0)	4,851 (0)	8,181 (224)	6,197 (619)	4,285 (1,051)	0.310
Good	− 1,207 (0)	2,169 (0)	5,451 (0)	8,885 (0)	12,067 (251)	10,155 (645)	0.262
Excellent	− 607 (0)	2,869 (0)	6,051 (0)	9,485 (0)	12,773 (0)	16,015 (278)	0.071
Weighted average net income†	−$1,911	$1,206	$3,582	*$5,102*	$4,848	$3,304	1.000

* Figures in parentheses are feed deficits (in AUM's); other figures are net incomes. Negative numbers represent negatine net incomes (losses).
† Highest weighted average net income in italic indicates optimum stocking rate.

TABLE 18

NET INCOME FOR COMBINATIONS OF STOCKING RATES AND RANGE CONDITIONS, PLAN 4, USING PROBABILITIES REVISED ON BASIS OF RANGE CONDITIONS, JANUARY 1*

January 1 range condition	Stocking rates and expected net incomes†					
	841 head	1,009 head	1,177 head	1,345 head	1,513 head	1,681 head
Very poor	−$2,749	−$2,008	−$1,362	−$ *615*	−$2,599	−$4,511
Poor	− 2,553	194	*1,098*	421	− 988	− 2,900
Fair	− 1,987	1,363	3,580	*5,381*	4,430	2,518
Normal	− 1,927	1,449	4,689	*5,974*	5,023	3,111
Good	− 1,207	2,191	5,451	8,862	*10,920*	10,153
Excellent	− 907	2,519	5,751	9,185	12,420	*13,085*

* Revised probabilities technically are *a posteriori* probabilities calculated in Appendix table A-6.
† Italic net income figures indicate the optimum stocking rate for each January 1 range condition. Negative numbers represent negative net incomes (losses).

come of $5,102. A more realistic picture is presented when the rancher observes the January 1 range condition report and revises the probabilities as discussed for plan 3. The decision rules now are:

When very poor range conditions exist on January 1, stock 1,345 head.
When poor range conditions exist on January 1, stock 1,177 head.
When fair or normal range conditions exist on January 1, stock 1,345 head.
When good range conditions exist on January 1, stock 1,513 head.
When excellent range conditions exist on January 1, stock 1,681 head.

The value of using the January 1 range condition to revise the probabilities of spring range conditions is more substantial in plan 4 than in the previous case of the combined cow herd plus feeders. The long-run average net income by making the January 1 range observation is $5,865 (calculated from table 18), but using only the long-run probabilities of the range conditions results in a net income of $5,102 (table 17). The difference between these values is $763—a measure of the usefulness of trying to predict the true spring range condition on the basis of existing range conditions on January 1.

The second situation considered under plan 4 is one where the rancher sells the steers as soon as the range feed supplies are exhausted. This means that in years

TABLE 19

NET INCOMES FOR PLAN 4 FOR VARIOUS RANGE CONDITIONS (CATTLE SOLD WHEN FEED SUPPLIES EXHAUSTED)

Range conditions	Stocking rates and net incomes*						Probabilities
	841 head	1,009 head	1,177 head	1,345 head	1,513 head	1,681 head	
Very poor	−$3,691	−$5,586	−$4,406	−$6,187	−$8,431	−$5,062	0.048
Poor	− 3,007	237	− 1,751	187	− 1,703	− 2,500	0.119
Fair	− 2,407	969	4,147	2,448	− 189	4,878	0.190
Normal	− 1,807	1,569	4,851	8,181	5,779	6,397	0.310
Good	− 1,207	2,169	5,451	8,885	12,067	12,079	0.262
Excellent	− 607	2,769	6,051	9,485	12,773	16,015	0.071
Weighted average net income†	−$1,911	$1,198	$3,733	$5,731	$5,222	*$6,678*	1.000

* Negative numbers represent negative net incomes (losses).
† Highest weighted average net income in italic indicates optimum stocking rate.

TABLE 20

NET INCOMES FOR PLAN 4 FOR VARIOUS RANGE CONDITIONS USING PROBABILITIES REVISED ON BASIS OF RANGE CONDITIONS, JANUARY 1; CATTLE SOLD WHEN FEED SUPPLIES ARE EXHAUSTED*

Observed January 1 range condition	Stocking rates and expected net incomes†					
	841 head	1,009 head	1,177 head	1,345 head	1,513 head	1,681 head
Very poor	−$2,749	−$2,008	$ 222	$ *997*	−$1,326	$ 668
Poor	− 2,553	194	1,450	2,084	412	*2,280*
Fair	− 1,987	1,363	3,580	*6,150*	4,933	5,602
Normal	− 1,927	1,449	4,689	6,029	4,649	*6,926*
Good	− 1,207	2,169	5,451	8,862	10,827	*11,691*
Excellent	− 907	2,469	5,751	9,190	12,420	*14,047*

* Revised probabilities technically are *a posteriori* probabilities calculated in Appendix table A-6.
† Italic net income figures indicate the optimum stocking rate for each January 1 range condition. Negative numbers represent negative net incomes (losses).

of poor range conditions some cattle are sold earlier at lighter weights, but it is not necessary to feed expensive hay when feed supplies run short. The restriction is again made that the rancher will not sell the feeders before 45 days on range (until April 1) even if feed is short before this time. Table 19 gives the net farm income for each of the stocking alternatives and possible range conditions. The most profitable alternative under this situation is to stock the maximum number of 1,681 head and sell them off after April 1, as feed supplies become exhausted. The somewhat erratic nature of the income figures is due to monthly changes in the selling prices between April and July (table 3). The expected income from stocking 1,681 head, using only the long-run probabilities of the range conditions, is $6,678 (table 19).

Since the buying dates for this situation are in January, it is possible to use the revised probabilities already calculated in Appendix table A-6 to find the optimum stocking rate given a certain January 1 observation of range conditions. The set of most profitable stocking rates, given the particular January 1 range condition observed, is: very poor range conditions, stock 1,345 head; poor range conditions, stock 1,681 head; fair range conditions, stock 1,345 head; normal, good, or excellent range conditions, stock 1,681 head (table 20).

The long-run weighted average income calculated from table 20 is $6,816 compared with $6,678 from table 19. Therefore, using the January 1 range conditions to revise the probabilities increases the average annual net income by $138.

Uncertainty Due to Prices

Plan 6. All-stocker Operation, with Stockers Sold as Slaughter Steers

Plan 6 is an all-stocker operation with 500-pound steers bought October 1, and carried through winter plus a 90-day fattening period from June 1 to September 1 the following summer. Two major sequential decisions are involved: first, determination of the number of animals to stock in October; second, the decision of whether to sell the feeders June 1 or carry them through the summer fattening period. The first decision depends primarily on range conditions, while the second decision depends on expected prices.

It is assumed that the operator makes the first decision regarding the range-stocking rate under uncertain range conditions as shown earlier for plan 3, table 21. That is, the operator selects the optimum stocking rate of 1,210 head. The second decision to be made by June 1 involves only two alternatives: (1) sell off the feeders June 1 or (2) feed out to slaughter weight for sale September 1. This decision depends on the feeder price prevailing June 1 and the probabilities of various positive or minus price margins between feeder cattle prices June 1 and slaughter cattle prices September 1.

TABLE 21

COMPARISON OF WEIGHTED AVERAGE NET INCOMES FOR SELLING FEEDERS JUNE 1 OR FEEDING OUT TO SLAUGHTER WEIGHT IN SEPTEMBER, PLAN 6*

June price	Sell June 1 at observed price	Sell, September 1†	Increased income from keep and sell September 1
dollars per cwt.	*dollars*		
16	*−58,318*	−62,186	− 3,868
17	*−49,662*	−51,115	− 1,453
18	−41,007	*−40,043*	964
19	−32,351	*−28,972*	3,379
20	−23,696	*−17,900*	5,796
21	−15,040	*− 6,828*	8,212
22	− 6,385	*− 4,242*	10,627
23	2,271	*15,315*	13,044
24	10,926	*26,387*	15,461
25	19,582	*37,459*	17,877
26	28,237	*48,530*	20,293
27	36,892	*59,602*	22,710
28	45,548	*70,674*	25,126
29	54,203	*81,745*	27,542
30	62,859	*92,817*	29,958
31	71,514	*103,889*	32,375

* Italic net income figures indicate the optimum decision for each June price. Negative numbers represent negative net incomes (losses).

† Technically, expected net income using *a posteriori* probabilities of alternative price margins from table 9.

Table 21 gives the incomes for "sell" and "keep" alternatives at each observed June price ranging from $16 to $31 per hundredweight. Each income from the sell alternative is simply the budgeted income from sale of the 1,210 feeders at the prevailing June price. Each income for the keep alternative, however, is a weighted average net income figure where the probabilities of various positive or negative June–September price margins (table 9) are used as the weights. A scatter diagram revealed no relationship between the absolute level of June prices and the June–September price margins. Thus, the same probability distribution of price margins (table 9) was used for each June price level, although this is somewhat unreasonable at either extreme. In this sense, the probabilities of table 9 are used as *a posteriori* probabilities associated with each observed June price level. Profits or losses in the October–June period are not relevant to the June decision. The relevant question is whether income is increased or decreased by continuing to feed the animals another 90 days. Thus, only the comparison of each pair of net income figures in table 21 is needed.

Table 21 emphasizes the extreme range in expected net income which can occur due to price variation. The decision to sell in June is selected only if the June feeder price is $17 per hundredweight or less. At higher prices, the alternative of keeping the steers for fattening and selling them September 1 is increasingly more attractive. It usually pays to feed out the animals because the probabilities in table 9 show that a zero to positive price margin is expected to occur over 80 per cent of the time (based on past experience).

Joint Uncertainty of Prices and Range Conditions

Plan 3 is the only operation discussed which involves decisions based on simultaneous consideration of uncertainty of range conditions and prices. This plan involves buying 500-pound stocker steers on October 1 and selling them the fol-

lowing June as 730-pound heavy feeders. The question to be answered is how many stockers should be bought October 1, given both the uncertainty of range conditions and of June prices.

The probabilities associated with the various range conditions are those given earlier in table 8. The probabilities of various October–June price margins are those given earlier in table 10.[6] To obtain the probabilities of both range conditions and price margins jointly, the two probabilities are multiplied. Altogether, there are a total of 42 possible range-price margin combinations (6 range conditions × 7 price margins) for each possible observed October 1 feeder price. For example, good range conditions and a + $1.00 October–June price margin are expected to occur simultaneously 5.5 per cent of the time. The probability of good range conditions is 0.262 (table 8); the probability of a +$1.00 October–June price margin is 0.210 (table 10). Therefore, the joint probability is $0.262 \times 0.210 = 0.055$.

Table 22 summarizes the weighted average net farm incomes for various stocking rates, given the October feeder price and considering simultaneously the uncertainty of price margins and range conditions. This table shows that, for an October price of $16 to $19 per hundredweight, 1,210 head should be selected; for an October price of $20 to $22 per hundredweight, 1,316 head should be selected; and for an October price of $23 per hundredweight or greater, 1,512 head should be selected. These results can be contrasted with the previous results for plan 3 where only range uncertainty was considered. In those cases (tables 15 and 16) the optimum stocking rates were 1,210 head (if fed through to June) and 1,361 head (if sold when feed supply exhausted). The expected price changes from October to June used in this analysis are generally more favorable than are the rather conservative normal prices

Table 22

WEIGHTED AVERAGE NET FARM INCOMES FOR VARIOUS STOCKING RATES AND OCTOBER PRICES, CONSIDERING JOINT UNCERTAINTY OF PRICE AND RANGE CONDITIONS

October 1 price	Stocking rates and net incomes*						
	0 head	756 head	908 head	1,059 head	1,210 head	1,361 head	1,512 head
dollars per cwt.	*dollars*						
16	−15,816	− 3,277	− 496	1,243	*2,232*†	1,173	− 917
17	−15,816	− 1,794	1,323	3,363	*4,656*	3,897	2,112
18	−15,816	− 311	3,142	5,483	*7,080*	6,621	5,141
19	−15,816	1,172	4,961	7,603	*9,504*	9,345	8,170
20	−15,816	2,655	6,780	9,723	11,928	*12,069*	11,199
21	−15,816	4,138	8,599	11,843	14,352	*14,793*	14,228
22	−15,816	5,621	10,418	13,963	16,776	*17,517*	17,257
23	−15,816	7,104	12,237	16,083	19,200	20,241	*20,286*
24	−15,816	8,587	14,056	18,203	21,624	22,965	*23,315*
25	−15,816	10,070	15,875	20,323	24,048	25,689	*26,344*

* Each net income figure calculated as weighted average, using 42 joint probabilities of price margin and range conditions as weights. Negative numbers represent negative net incomes (losses).

† Italic net income figures indicate the optimum decision for each October 1 price.

[6] The probability distribution of the October–June price margin was independent of the absolute October 1 feeder price. Thus, the price margin probabilities of table 10 are used as *a posteriori* probabilities for each observed October 1 price.

used previously, and therefore lead to higher stocking rates as more profitable, particularly at higher October 1 feeder prices. A similar result would occur from applying the joint probability approach to plan 4.

COMPARISON OF PARTS I AND II

In this report two different approaches were used to compare alternative range operations and stocking rates. Part I used linear programming methods to determine the stocking rates and income situations for the six alternative plans. The basic assumption behind this method was that the optimum number of cattle or calves to stock was that number which would completely utilize range feed production under normal range conditions.

Part II of this report uses a combination of linear programming (or budgeting) and statistical decision theory to select the optimum stocking rates for each of the main alternative plans. For each possible range condition or price condition the net incomes obtained from alternative stocking rates were determined by linear programming or budgeting. The optimum stocking rate(s) were then derived using the long run *a priori* or revised *a posteriori* probabilities associated with the various prices or range conditions.

Direct comparisons cannot be made between the net income figures obtained in Part I and the expected net income figures derived in Part II, although the net incomes of Part II are the same as those of Part I for the one cell of the net income table where normal conditions and normal stocking rates are considered. Rather, expected net incomes for stocking rates determined in Part I must be recomputed, using the long-run *a priori* probabilities developed in Part II. In such a comparison the expected incomes from the decision strategies of Part II always equal or exceed the corresponding net incomes from the decision strategies of Part I. A relevant question is to what extent the decision theory solutions have improved upon the results of programming solutions which use only normal price and range conditions.

Table 23 shows comparisons which can be made between the expected net incomes associated with the strategies derived in Parts I and II. Due to a nearly normal long-run *a priori* probability distribution of range conditions, the optimum stocking rates obtained in Parts I and II are nearly the same for most plans. When revised *a posteriori* probabilities are used, however, stocking rates are more variable and incomes are somewhat increased.

A general conclusion would seem to be that statistical decision theory is a useful supplement to linear programming or budgeting solutions which are based on assumed normal conditions. However, where the uncertain variables (price or range conditions) are nearly normally distributed about the normal or average condition assumed, the strategies and expected net incomes derived from statistical decision theory (Chernoff and Moses, 1959) will probably show little improvement over the conventional analysis. If the distribution of the uncertain variable is definitely skewed, decision theory should markedly improve the programming results.

Decision theory is of value to ranchers because it develops a net income table showing the nature and wide variety of possible outcomes under each range or price situation and alternative stocking rate. It is possible, however, that some managers will prefer decision strategies more conservative than those based on statistical decision theory (Bayes strategy). For example, a manager with

TABLE 23

COMPARISON OF EXPECTED NET FARM INCOMES FROM OPTIMUM STOCKING RATES DERIVED IN PART I AND PART II

Plan	Optimum stocking rate		Expected net income		Expected gain, Part II over Part I
	Part I	Part II	Part I	Part II	
			dollars		
1	360 cows	415 cows (*a priori* probability)	2,879*	2,957*	78
2	312 cows	312 cows (*a priori* probablity)	2,879*	2,879*	0
	312 cows	200 cows plus 685 steers (*a priori* probability)	2,879*	6,104	2,725
	312 cows	200 cows plus variable number steers (*a posteriori* probability)	2,879*	6,366	2,987
3	1,210 steers	1,210 steers (*a priori* probability)	6,939	6,939	0
	1,210 steers	1,361 steers, sell when feed supply exhausred (*a priori* porbability)	6,939	8,034	1,095
4	1,345 steers	1,345 steers (*a priori* probability)	5,102	5,102	0
	1,345 steers	1,681 steers, sell when feed supply exhausted (*a priori* probability)	5,102	6,678	1,576
	1,345 steers	1,177 to 1,681 steers (*a posteriori* probability)	5,102	5,865	763
	1,345 steers	1,345 to 1,681 steers, sell when supply exhausted (*a posteriori* probability)	5,102	6,816	1,714
6	1,205 steers	1,205 steers (finish or not depending on June price)	19,899†	20,535†	636

* Interest on cow herd not included as a cash cost; assumes herd fully owned.
† Computed from probability distributions on the June price; not included in text.

a short-run planning horizon may choose a stocking rate which guarantees some minimum level of income regardless of the range condition or price, even though the long-run expected income is lower than that from the optimum statistical decision. Likewise, a "gambler" might prefer a stocking rate with some small probability of windfall profits, even if the long-run expected income is lower than that from the optimum statistical decision.[7] In each case the complete net income (payoff) tables have been given in order to allow individual ranchers to make choices other than the optimum statistical decision (Bayes strategy).

SUMMARY AND CONCLUSIONS

The plans with a beef cow herd, where the calves are sold either as weaners or yearlings, were rather unprofitable as the volume of business is so small that only enough gross income is generated to approximately cover cash costs plus depreciation. It seems doubtful that many ranchers could long stay in business with a strictly cow-calf operation. Certainly an operator could not ordinarily buy a foothill ranch at present prices and pay for it out of earnings from a cow-calf operation.

In plans where the beef cow herd is eliminated and replaced with 500–550-pound stockers purchased in the fall or winter and sold at the end of the green-grass season, net incomes are increased

[7] Technically, these may be rational choices if the decision is not considered by the rancher as a repetitive decision which will average out in the long run, and if his utility function for money is nonlinear over the relevant range of income.

by about $10,000 per year over the cow-herd operations. While these plans cover cash costs and depreciation, they still provide returns to capital and management below market rates.

One proposal to intensify foothill beef operations is to feed out the steers to slaughter weight, feeding them on all-concentrate ration while confined on range pasture. While this is atypical, results show that an all-stocker operation using range during the winter green-feed period, followed by a 90-day fattening period in the summer, substantially increases the expected net income. This is the only plan considered which covers all costs, including a market rate of interest (6–7 per cent) on the capital investment. Of course, the increasing dependence on buying and selling cattle and on purchased barley greatly increases the risk and management responsibility compared with the other plans.

Variability in income due to fluctuations in range conditions and prices was considerable. Net farm income from the beef cow herd operations fluctuated from about – $11,000 to $7,500, due to variation in range conditions alone. The all-stocker operation showed income variation of from about – $10,000 to $9,000, due to range conditions. Variability in income due to price fluctuations was, of course, most important for the all-stocker finishing operations. Here the expected net income varied from about – $18,000 to $37,000 due to price fluctuations from $20 to $25 per hundredweight in June feeder prices alone.

Statistical decision theory was used to supplement the plans developed from linear programming based on assumed normal range conditions and prices. Due to a nearly normal probability distribution of range conditions based on 40 years of data, optimum stocking rates developed from decision theory varied only slightly from those developed by linear programming. In general, decision theory suggested that it often pays to stock for somewhat above-average conditions rather than for normal conditions and, when necessary, to supplement the animals or sell early when range feed supplies become short.

Statistical decision theory presents an approach to many problems of decision-making under uncertainty which ranchers could apply rather easily. It is applicable to decisions which are made repetitively through time, such as stocking rate decisions. This approach requires that the manager attach probabilities to the possible alternative outcomes under uncertainty. These probabilities can be determined either objectively from historical data or subjectively based on the manager's best personal assessment of the situation. Given these probabilities, the optimum decision is simply that choice which maximizes the weighted average income, where the probabilities are used as weights. Even in cases where statistical decisions based on net income may not be appropriate (such as "once-and-for-all" decisions), decision theory provides a useful framework within which to consider the problem.

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To simplify the information, it is sometimes necessary to use trade names of products or equipment. No endorsement of named products is intended nor is criticism implied of similar products not mentioned.

APPENDIX A

Appendix Table A-1

INDEX OF MONTHLY RANGE CONDITIONS (AS OF THE FIRST OF THE MONTH) FOR DISTRICT 5, SACRAMENTO VALLEY*

Year	Month											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1922	75	66	57	74	73	82	85	88	74	78	87	89
1923	96	99	94	65	98	98	90	90	91	86	83	61
1924	57	46	73	59	42	47	53	51	55	51	75	93
1925	84	71	94	105	108	95	98	103	94	93	88	80
1926	82	71	95	90	97	93	95	93	94	85	90	95
1927	95	95	96	102	100	96	90	87	86	84	81	89
1928	88	86	87	100	98	95	90	90	90	88	85	85
1929	80	80	74	76	66	63	67	71	73	71	66	44
1930	64	72	84	92	89	90	85	85	84	83	85	76
1931	55	62	77	76	50	52	56	53	52	51	51	49
1932	63	63	54	76	73	77	78	78	77	76	72	61
1933	55	55	50	63	68	63	63	67	62	62	59	59
1934	71	86	94	97	88	83	77	70	65	63	61	82
1935	94	90	96	96	102	99	94	92	89	87	86	81
1936	71	85	87	86	88	87	86	82	79	73	68	62
1937	45	23	32	58	70	68	70	73	71	71	80	92
1938	93	95	96	98	99	95	90	86	84	85	84	70
1939	74	67	53	58	54	56	54	56	58	56	57	45
1940	44	62	72	88	96	94	86	86	82	84	82	86
1941	86	84	88	92	92	97	88	87	86	82	79	72
1942	92	84	84	80	91	92	87	87	86	81	80	77
1943	81	75	81	90	90	84	84	83	82	82	76	66
1944	63	64	64	61	60	68	70	73	73	73	72	82
1945	91	86	84	87	81	79	79	78	80	80	77	88
1946	84	81	71	73	79	77	76	80	79	78	74	56
1947	71	56	72	84	86	79	72	72	72	68	80	88
1948	80	65	54	66	86	91	88	84	82	80	77	70
1949	65	44	47	74	68	67	69	73	72	70	62	66
1950	61	63	74	82	83	81	81	80	81	76	75	94
1951	92	88	89	84	79	85	81	84	83	81	79	82
1952	81	78	81	72	85	87	85	84	84	81	79	70
1953	76	81	67	70	73	82	85	82	80	76	74	76
1954	71	72	76	86	93	91	85	81	83	76	74	76
1955	73	69	66	61	70	78	79	78	79	72	70	73
1956	74	74	74	71	79	87	83	82	81	76	78	70
1957	66	60	73	81	85	88	82	79	80	82	92	85
1958	87	86	89	88	88	88	85	85	82	83	82	68
1959	63	74	79	70	72	68	72	59	68	74	67	62
1960	59	61	68	77	79	81	79	73	69	73	66	78
1961	81	80	81	83	80	83	78	73	74	77	73	66
1962	73	67	78	81	77	78	77	76	76	76	86	89
1963	90	68	85	87	90	92	87	86	84	81	89	91
1964	86	82	75	72	68	70	70	69	70	73	69	78

* Index meaning: 49 or less, very bad; 50–59 bad; 60–69 poor; 70–79 fair; 80–89 good; 90–99 very good; 100 and over, excellent.

Source: California Crop and Livestock Reporting Service, 1922–1964.

Appendix Table A-2

AVERAGE PRICES BY GRADE AND MONTH AT SELECTED MARKETS

Year	Kansas City*		Stockton†		Chicago*	
	Stocker and feeder prices, all weights and grades		Stocker and feeder prices, 500–800 pounds, (average of good and choice)		Slaughter steer prices, September (900–1,100 pounds)	
	October	June	October	June	Choice‡	Good§
	dollars per hundred pounds					
1925	7.13	6.14	.....	.....	11.88	9.11
1926	7.19	7.42	.....	.....	10.33	9.18
1927	9.08	8.30	.....	.....	13.31	10.54
1928	11.06	11.18	.....	.....	16.09	13.84
1929	9.94	11.52	.....	.....	14.13	12.32
1930	7.06	7.78	.....	.....	10.89	9.39
1931	5.05	5.82	.....	.....	8.66	6.82
1932	4.47	4.54	.....	.....	8.21	6.88
1933	3.68	4.68	.....	.....	5.89	5.19
1934	3.92	4.08	.....	.....	8.20	5.97
1935	6.88	6.88	.....	.....	10.70	8.62
1936	6.01	6.56	.....	.....	8.86	7.85
1937	7.58	7.87	.....	.....	13.88	10.40
1938	7.47	7.51	.....	.....	10.03	8.19
1939	8.04	7.94	.....	.....	10.20	9.00
1940	8.52	8.05	.....	.....	11.15	9.08
1941	9.53	9.90	.....	.....	11.56	10.38
1942	11.83	11.83	.....	.....	14.63	12.87
1943	11.36	14.38	.....	.....	15.27	13.58
1944	11.50	11.65	.....	.....	16.26	13.40
1945	12.62	13.73	.....	.....	16.15	13.30
1946	16.42	15.72	.....	.....	19.58	17.44
1947	20.96	21.11	.....	.....	29.43	22.60
1948	24.41	26.96	.....	.....	34.49	27.59
1949	20.57	22.53	.....	.....	28.22	23.01
1950	26.92	27.44	.....	.....	30.32	28.07
1951	31.97	32.83	.....	.....	36.68	33.73
1952	22.76	27.21	24.88	30.34	32.53	28.96
1953	15.74	15.22	16.14	19.13	25.87	21.87
1954	18.84	18.20	19.21	20.62	25.00	22.18
1955	18.02	19.03	17.94	19.84	22.69	21.28
1956	17.31	17.02	17.40	17.90	27.27	23.49
1957	20.18	20.20	20.60	20.07	24.98	22.86
1958	25.80	25.38	26.22	26.38	26.70	25.56
1959	24.41	27.24	26.40	27.84	27.62	26.50
1960	21.59	23.50	22.88	24.62	24.80	23.57
1961	22.97	21.81	22.90	22.47	24.34	23.57
1962	25.38	23.23	24.12	24.16	29.85	27.62
1963	.....	.....	22.28	23.67	.....	.....

* Source: U. S. Department of Agriculture, Agricultural Marketing Service, 1958, 1963.
† Source: U. S. Department of Agriculture, Federal-State Market News Service, 1964.
‡ Good grade, 1922–1950.
§ Included in medium grade, 1922–1950.

Appendix Table A-3

PRODUCTION COSTS FOR STAND ESTABLISHMENT OF IMPROVED CLOVERS*

Operation	Hours per acre†	Fuel and repairs (dollars)†	Materials	Total cost (dollars)‡
Plow	0.67	3.32		3.32
Harrow	0.3	0.60		0.60
Fertilize	0.2	0.23	100 pounds nitrogen = $14.00 200 pounds sulfur = $ 4.40	18.63
Plant	0.4	0.96	Seed = $ 1.49 Innoculant 0.03 pounds = $ 0.02	2.47
Total	...	....		25.02 Prorate over 10 years = $2.50 per acre per year.

* Includes Subterranean Crimson and Rose clovers.
† Source: Reed, A. D., *Machinery Costs and Related Data*, University of California, Agricultural Extension Service, Davis, California, May 1959, (unpublished).
‡ Actual figure from case-study ranch.

Appendix Table A-4

PRODUCTION COSTS FOR DRYLAND BARLEY*

Operation	Hours per acre†	Fuel and repairs (dollars)†	Materials	Total cost per acre (dollars)‡
Plow	0.67	3.32	.....	3.32
Disc three times	0.9	2.07	.....	2.07
Harrow	0.2	0.40	.....	0.40
Plant	0.4	0.96	100 pounds seed at $3.00 per cwt.	3.96
Harrow	0.2	0.40	.....	0.40
Combine	...	....	$5.00 per acre plus 25c per cwt. = $9.50	9.50
Haul	...	....	.....	1.00
Total	...	....	.....	20.65

* Assumes yield of 18 cwt. per acre.
† Source: Reed, A. D., *Machinery Costs and Related Data*, University of California, Agricultural Extension Service, Davis, California, May, 1959. (unpublished).
‡ Actual figure from case-study ranch.

Appendix Table A-5

PRODUCTION COSTS FOR 25 ACRES OF IRRIGATED PASTURE*

Operation	Material	Total cost (dollars)
Pumping	.....	516.16
Fertilizing	5,000 pounds 16-20 or 800 pounds nitrogen at 14c 1,000 pounds phosphate at 10c	 112.00 100.00
Total	.....	728.16

* Figures from case-study ranch. Labor costs are considered a fixed cost for entire ranch, so are not included here.

Appendix Table A-6

DETERMINATION OF *A POSTERIORI* PROBABILITIES OF SPRING RANGE CONDITIONS BASED ON OBSERVED RANGE CONDITIONS, JANUARY 1*

A. Conditional probabilities of Z_i given θ_i, $P(Z/\theta)$

Spring range condition (θ_i)	Observed range condition, January 1 (Z_i)						*A priori* probability $P(\theta)$
	Very poor	Poor	Fair	Normal	Good	Excellent	
Very poor	0.500	0.500	.....	.....	.....	.....	0.048
Poor	.....	0.600	0.400	.....	.....	.....	0.119
Fair	.....	0.375	0.125	0.500	.....	.....	0.190
Normal	0.077	0.077	0.385	0.307	0.154	.....	0.310
Good	.....	0.091	0.182	0.182	0.454	0.091	0.262
Excellent	.....	.....	.....	.....	0.667	0.333	0.071

B. Joint probabilities of $\theta = \theta_i$ and $Z = Z_i$, $P(Z/\theta) \times P(\theta)$

Spring range condition (θ_i)	Observed range condition, January 1 (Z_i)					
	Very poor	Poor	Fair	Normal	Good	Excellent
Very poor	0.024	0.024	.....	.....	.....	.....
Poor	.....	0.071	0.048	.....	.....	.....
Fair	.....	0.071	0.024	0.095	.....	.....
Normal	0.024	0.024	0.119	0.095	0.048	.....
Good	.....	0.024	0.048	0.048	0.119	0.024
Excellent	.....	.....	.....	.....	0.048	0.024
$P(Z)$	0.048	0.214	0.239	0.238	0.215	0.048

C. *A posteriori* probabilities w_i of θ_i given Z_i, $w = P(\theta/Z)$

Spring range condition (θ_i)	Observed range condition, January 1 (Z_i)					
	Very poor	Poor	Fair	Normal	Good	Excellent
Very poor	0.500	0.111	.....	.....	.....	.....
Poor	.....	0.333	0.200	.....	.....	.....
Fair	.....	0.333	0.100	0.400	.....	.....
Normal	0.500	0.111	0.500	0.400	0.222	.....
Good	.....	0.111	0.200	0.200	0.556	0.500
Excellent	.....	.....	.....	.....	0.222	0.500

* For explanation of method of calculation of *a posteriori* probabilities, see Appendix B.

APPENDIX B. STATISTICAL DECISION THEORY

Statistical decision theory is used in developing various strategies to cope with risk and uncertainty[8] in Part II of this report. The formal theory used is Bayesian statistics. In general, a Bayes strategy maximizes the weighted average (expected value) of the various possible gains or minimizes the weighted average (expected value) of possible losses. Expected monetary gains (losses) are an appropriate crite-

[8] Formally, "risk" refers to situations in which the probability distribution of occurrences can be estimated, while "uncertainty" refers to those situations where the probabilities cannot be estimated. In these terms, our analysis deals only with risk situations. However, we use the terms *risk* and *uncertainty* interchangeably in this report. (See: Knight, F. H., *Risk, Uncertainty and Profit*, Boston: Houghton Mifflin Company, 1921.)

rion only if we are dealing with a reoccurring type of decision problem. In this case it is meaningful to find the expected monetary value of each action and choose that one which has the highest value. However, in the case of a single "once-and-for-all" decision, utility theory generally should be applied, and the solution found by choosing that strategy with the greatest expected utility. Empirically, this would require derivation of meaningful utility functions.

The logic and computational procedures underlying Bayes strategies are presented in the simple numerical example of tables B-1 to B-6. Table B-1 shows the payoffs associated with given actions (a_i) when a particular "state of nature" (θ_i) occurs. In the empirical context of this report, the actions (a_i) represent various stocking rates which the manager could adopt. The states of nature (θ_i) represent either various levels of range conditions, various price levels or combinations of the two, depending on the problem at hand. The payoffs are measured in terms of net income. Suppose a_1, a_2, and a_3 represent stocking rates of 1,000, 1,500, and 2,000 head of stockers, respectively, and θ_1, θ_2, and θ_3 represent below average, average, and above average weather and range conditions. The numbers in the body of table B-1 then represent the net farm incomes which result from each combination of stocking rate and range condition.

If the state of nature were known, it would be a simple matter to select the profit maximizing action. For example, if the manager were certain that range condition θ_1 (below average) would occur, he would select stocking rate a_1 (1,000 head) since this gives a loss of only – $1,000 compared with larger losses of – $4,000 and – $7,000 for stocking rates a_2 and a_3, respectively. Of course, the manager is in fact unable to predict the true state of nature in any particular year. But let us assume that he knows the *a priori* probability distribution of the states of nature—i.e., the long-run probabilities of various range conditions, based on a long personal experience or on analysis of published data on weather or range conditions, or both. Given these *a priori* probabilities, the manager can compute his expected net income for each action by weighting the payoffs for each action by the probability distribution of the states of nature. Table B-1 shows that action a_2 (stocking 1,500 head), with an expected net income of $4,300, would be the optimum strategy under conditions where the *a priori* probabilities of θ_1, θ_2, and θ_3 are 0.3, 0.4, and 0.3, respectively.

When some observation or experiment can be made each year to improve knowledge about the true state of nature in that particular year, the problem is said to be a "data" rather than a "no-data" problem. Let us assume that the manager normally buys his cattle in January. He has observed that if range conditions are good on January 1, there is a higher probability of range conditions remaining favorable that year than if conditions are poor on January 1. More formally, he might construct table B-2, which shows the conditional probabilities of observing certain range conditions Z_i on January 1 (let Z_1 = below average, Z_2 = average, and Z_3 = above average range conditions on January 1) when the subsequent true range condition will prove to be θ_i.

Table B-3 can then be constructed, showing the joint probabilities of the various combinations of θ_1 and Z_1, by multiplying $P\ (Z|\theta) \times P\ (\theta)$. For example, table B-2 shows a 0.3 probability of observing Z_2 when the true state of nature is θ_2, $P\ (Z_2|\theta_2) = 0.3$. But the probability of θ_2 is 0.4, $P\ (\theta_2) = 0.4$. Hence, the joint probability of observing Z_2 when the true state of nature is θ_2 is $P\ (Z_2|\theta_2) \times P\ (\theta_2) = 0.3 \times 0.4 = 0.12$ (see table B-3). Table B-4 can then be constructed, showing the *a posteriori* probabilities, $P\ (\theta|Z = \frac{[P(Z|\theta) \times P(\theta)]}{P\ (Z)}$. These provide the conditional probabilities of

the various θ_i states of nature, given that a particular Z_i range condition is observed on January 1. For example, the probabilities of observing Z_2 when the true states of nature are θ_1, θ_2, θ_3, are 0.06, 0.12, and 0.06, respectively (table B-3). In total, Z_2 is observed 0.24 of the time, $P(Z_2) = 0.06 + 0.12 + 0.06 = 0.24$. Hence, when Z_2 is observed, the conditional probabilities of the true states of nature are: $P(\theta_1|Z_2) = 0.06 \div 0.24 = 0.25$; $P(\theta_2|Z_2) = 0.12 \div 0.24 = 0.50$; and $P(\theta_3|Z_2) = 0.06 \div 0.24 = 0.25$ (table B-4).

The manager observes that the range condition on January 1 is, for example, Z_1. He then applies the *a posteriori* probabilities $P(\theta_i|Z_1)$ to the original payoff matrix and obtains an expected net income for each action a_i. (This procedure is shown in table B-5, assuming that range condition Z_1 is observed on January 1.) In this case, a_1 is the optimum strategy with the maximum gain (minimum loss) of –$500. Similarly, table B-6 gives the final summary of expected net incomes and optimum strategies (underlined) when various Z's are observed. The optimum "strategy bundle" is as follows: If Z_1 is observed, select a_1; if Z_2 is observed, select a_2; if Z_3 is observed, select a_3.

Finally, the expected value of following this strategy bundle can be computed by multiplying the expected values of the optimum action for each observed Z by the probability of observing Z, $P(Z)$. This expected income from the "data" problem is shown to be $5,400 (bottom, table B-6). The expected income from the "no data" problem was shown to be $4,300 (table B-1). Hence, the improvement in expected income by observing the Z values (range conditions, January 1) and revising probability estimates and actions accordingly is shown to be $5,400 – $4,300 = $1,100. This value ($1,100) is called "the value of the experiment."

Appendix Table B-1

PAYOFFS (NET INCOMES) OF ALTERNATIVE ACTIONS UNDER VARIOUS STATES OF NATURE, AND EXPECTED VALUES OF ACTIONS a_i GIVEN *A PRIORI* PROBABILITIES $P(\theta)$

States of nature	Action			*A priori* probabilities of $\theta_i = P(\theta)$
	a_1	a_2	a_3	
θ_1	−1,000	−4,000	−7,000	0.3
θ_2	1,000	7,000	4,000	0.4
θ_3	3,000	9,000	15,000	0.3
Expected value	1,000	*4,300*	4,000	...

Appendix Table B-2

CONDITIONAL PROBABILITIES OF Z_i GIVEN θ_i, $P(Z/\theta)$

States of nature	Observations			$P(\theta)$
	Z_1	Z_2	Z_3	
θ_1	0.8	0.2	0	0.3
θ_2	0.2	0.3	0.5	0.4
θ_3	0	0.2	0.8	0.3

Appendix Table B-3

JOINT PROBABILITIES OF $\theta = \theta_i$ AND $Z = Z_i$, $P(\theta = \theta_i \text{ AND } Z = Z_i) = P(Z/\theta) \times P(\theta)$

States of nature	Observations		
	Z_1	Z_2	Z_3
θ_1	0.24	0.06	0
θ_2	0.08	0.12	0.20
θ_3	0	0.06	0.24
$P(Z)$	0.32	0.24	0.44

Appendix Table B-4

A POSTERIORI PROBABILITIES w_i OF θ_i GIVEN Z_i, $w = P(\theta/Z) = [P(Z/\theta) \times P(\theta)]/P(Z)$

States of nature	Observations		
	Z_1	Z_2	Z_3
θ_1	0.75	0.25	0
θ_2	0.25	0.50	0.45
θ_3	0	0.25	0.55

Appendix Table B-5

COMPUTATION OF EXPECTED VALUES OF ALTERNATIVE ACTIONS a_i, ASSUMING Z_1 IS OBSERVED

States of nature	Action			*A Posteriori* probabilities $w_1 = P(\theta/Z_1)$
	a_1	a_2	a_3	
θ_1	−1,000	−4,000	−7,000	0.75
θ_2	1,000	7,000	4,000	0.25
θ_3	3,000	9,000	15,000	0
Expected value	*− 500*	−1,250	−4,250	....

Appendix Table B-6

SUMMARY OF EXPECTED VALUES OF ALTERNATIVE ACTIONS a_i, ASSUMING VARIOUS Z_i ARE OBSERVED, AND EXPECTED VALUE OF OPTIMUM STRATEGY BUNDLE

Given observation	Action			$P(Z)$
	a_1	a_2	a_3	
Z_1	*− 500*	−1,250	− 4,250	0.32
Z_2	1,000	*4,750*	4,000	0.24
Z_3	2,100	8,100	*10,050*	0.44
Expected value of optimum strategy bundle*		(5,400)		....

* Summation of italicized actions times $P(Z)$.